GRANITES

AND

GREENSTONES

A Series of Tables and Notes for
Students of Petrology

BY

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London
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3 LUDGATE CIRCUS BUILDINGS, E.C
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NOTE ON PREPARATION OF MODELS.

WITH a few exceptions, models to illustrate the optical characters and the cleavage of the principal biaxial rock-forming minerals may be constructed from the figures given in the second part of this book. In doing this, it will be found most convenient to double the dimensions, copying the figures upon moderately stout cardboard. The separate pieces, when cut out, may be fixed together in their proper positions by means of coaguline, and they may then be mounted upon wooden match-ends fixed in holes bored in small, flat pieces of wood, which serve as feet. Each pinacoidal plane of the model should be inscribed with its proper symbol, and the label on the foot should be so placed that the plane corresponding to 100 should in every case face the observer. Such models will be found extremely convenient for reference, and the student will derive some benefit from their construction. In fixing the models, Kay's coaguline is much to be preferred to thick gum, as its sets more rapidly.

Errata.

PAGE

34, line 16 from bottom, for "α, β and γ," read "γ, β and α."
35 ,, 11 ,, ,, for "Chalunes," read "Chaulnes."
40 ,, 3 ,, ,, after "that" insert "on meeting the film of balsam."
57 ,, 6 and 7 from bottom, for "normal to these common tangent planes or circular sections of the ellipsoid" read "following these surfaces of the cones."
57, last line for "Ox Ox," read "The directions Ox," and for "external" read "internal."
58, top line for "Of these" read "Here."
58, line 3 from top, for "ex-" read "in-."
58 ,, 5 ,, ,, for "internal" read "external."
82, ,, 6 ,, bottom, before "optic," insert "traces of the"
92 ,, 11 ,, ,, for "thickening," read "thinning;" and for "greater," read "less."
92 ,, 7 ,, ,, for "thickening," read "thinning."
92 ,, 6 ,, ,, for "greater," read "less."
93, lines 6, 20, and 24 from top, for "thickening," read "thinning."
106, line 6 from bottom, for "on the basal plane" read "on a face of the cube."
107 ,, 10 ,, top, before "magnetite," insert "a moderate amount of."
114 ,, 16 ,, bottom, after "O_{12}," add "$+ 2H_2O$."
125 ,, 16 ,, top, before "absence," insert "usual."
162 ,, 9 ,, bottom, for "(100)" read "(110)."
165, foot-note, for "Yarbuch," read "Jahrbuch."
167, line 16 from bottom, erase "hence."
195 ,, 20 ,, ,, for "of," read "between"; and for "axis," read "axes."
208 ,, 4 ,, top, for "*c c*," read "P P."
208, Fig. 105, for "C C," read "P P," insert *c* beside central dot on the line joining *b b'*, and erase "001."
Note.—In this figure the plane of projection is at right angles to the vertical axis *c*.
208, Fig. 106, for "c c," read "*c c*."
Note.—In this figure the plane of plane of projection is on s s' in Fig. 105—*i.e.*, not quite parallel to the clinopinacoid, 010, which in Fig. 105 is parallel to P P.
218, line 6 from bottom, erase "not particularly"; for "but," read "and": and for "so," read "also strong."
219, Fig. 115, for "a," read "c"; and for "c," read "a."
233, line 9 from top, for "acute," read "obtuse."
221, Fig. 124, for "$\bar{1}01$" read "$10\bar{1}$."
245, after "sphene," insert "Indices, $\alpha = 1{\cdot}8876$, $\beta = 1{\cdot}8940$, $\gamma = 2{\cdot}0093$, $2V = 23° - 34°$.

ROCK-FORMING MINERALS.

Supplementary List of Errata.

PAGE.

33, fig. 14, transpose α and γ both in the diagram and beneath it.

35, line 3 from bottom, after "medium", insert "this is due to total reflection."

36 ,, 2 ,, ,, for "poles" read "the solid angles through which the principal axis passes."

40 ,, 11 ,, top, for "are" read "is," and for "those" read "that."

40 ,, 23 ,, ,, after "for" insert "complete."

44, lines 11 and 12 from top, for "around this axis and at right angles to it" substitute "equally inclined to this axis."

45, line 13 from top, erase "vibrations of the."

45, lines 2 and 3 from bottom, for "or those directions in which a crystal transmits no light when viewed between crossed nicols" read "a crystal plate attaining its maximum obscurity when these directions lie in the planes containing the principal sections of the crossed nicols."

48, line 22 from top, before "correspond" insert "necessarily."

53 ,, 3 ,, bottom, for "in the plane of" read "parallel to."

58 ,, 10 ,, top, erase "or directions of maximum extinction."

58 ,, 21 ,, ,, after "bisectrix" insert "for a given colour."

63 ,, 1 ,, ,, for "not unfrequently possess" read "in many cases exhibit."

104 ,, 9 ,, ,, for "travelling" read "vibrating."

104 ,, 10 ,, ,, for "passing" read "vibrating."

109 ,, 8 ,, bottom, after "found" insert "in Pyreneeite and Ouwarowite, the former from Auerbach."

123 ,, 11 ,, ,, for "Reusch's" read "Baumhauer's."

130 ,, 9 ,, top, for "D'or" read "Dore."

130 ,, 15 ,, ,, after "silica" insert "According to M. Lévy the minute fibres of Chalcedony are biaxial, optically positive and elongated parallel to a."

135, fig. 76, for "65° 35′" read "114° 25′."

135, line 4 from bottom, insert "Cleavage most perfect parallel to (110), less so to (100), imperfect to (111)."

143 ,, 15 ,, top, for "an" read "a symmetrical."

154, after last line add "and the double refraction is negative."

155, line 8 from top, after "positive" insert "except in Fayalite."

160 ,, 5 ,, ,, for "Chlorphyllite" read "Chlorophyllite."

166 & 167, for "Sillimannite" read "Sillimanite."

195, last line, for "Clino-diagonal" read "Ortho-diagonal," and for "Ortho-" read "Clino-."

202, line 15 from top, for "Mn" read "Mg."

222, ,, 8 ,, bottom, for "Baveno" read "Albite," and for "Carlsbad" read "Pericline."

226, fig. 120, for "$\bar{2}01$" read "$20\bar{1}$."

227 ,, 121, for "$\bar{1}01$" read "$10\bar{1}$," and for "$10\bar{1}$" read "$\bar{1}01$."

229, top line, for $\infty P \infty$ read $\infty \breve{P} \infty$.

FOOT-NOTE.—On previous page alter page 34, line 16 to line 19; page *233 to 223, and 221 to* 231.

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Frome, and London.

CONTENTS

Extracts from Works Published between the Years 1820 and 1860.

"Various classifications of volcanic substances have been proposed, among which the division into Trachytic and Basaltic seems to be that most commonly adopted."

Geological Manual, p. 137. 1833.

De la Beche.

"*Trap.*—Tabular greenstone and basaltic rocks, from their rising up in step-like masses, were originally so termed; but the name is now extended to all igneous rocks which are not either strictly Granitic or decidedly Volcanic."

Handbook of Geological Terms, 1859.

Page.

"Diabas. Syn. Grünstein z. Th. Diorit z. Th. Hyperit z. Th."

Handbuch der Lithologie. 1860.

Blum.

"The principle of separating from the trap or basalt the "greenstone protrusions," is in part correct; these intrusions consist of two kinds, namely, whin dykes or basaltic veins, and huge amorphous masses of greenstone, or greenstone-porphyry, which occasionally form large mountains, and which among igneous rocks are only secondary to granite in point of extent and importance."

Report on the Geology of Londonderry and parts of Tyrone and Fermanagh, p. 77. 1843.

Portlock.

"When these granite-veins are of a large size, they are termed *elvan-courses*. . . . In composition, these elvans are either shorl rock, eurite, felsparite, or even varieties of fine-grained granite."

A Treatise on Primary Geology, p. 22. 1834.

Boase.

"J'ai été le premier à donner le nom scientifique et général de *Diabase* à la roche décrite et caractérisée sous le nom de *Grünstein* par les minéralogistes allemands."

Classification et Caractères Minéralogiques des Roches, p. 80. 1827.

Brongniart.

"By the term granite is here understood every compound rock which is found in irregular masses beneath the lowest strata; including, further, those veins which proceed from them so as to traverse the adjoining rocks . . ."

A Geological Classification of Rocks, p. 225. 1821.

Mac Culloch.

"Granites no doubt vary in their chemical composition, and so do greenstones, yet they always so differ from each other as masses of matter that the one can never become the other from mere differences in cooling."

Researches in Theoretical Geology, p. 379. 1834.

De la Beche.

PREFATORY NOTE

THE title "Granites and Greenstones" has been chosen because it is a comprehensive one. The relation between granites and syenites and between rhyolites and trachytes induced the geologist of former days to look upon these rocks, with their associated dykes, as members of one great group, the most important and characteristic being GRANITE.

In like manner he broadly treated the diorites, gabbros, etc. (together with the basalts, dolerites, and lamprophyres), as representatives of another great group, to which the name GREENSTONE was given. No distinction was drawn between trachytes and andesites; the dyke rocks of the greenstone group were termed traps, while those of the granite group were called elvans. There were thus two great groups of eruptive rocks, Granites and Greenstones, and the geologist of the present day will do well to retain these time-honoured names for use in the field. They may not express very much, but what significance they have is broad, and they are far more valuable for use on a working map than the more precise names with which modern petrography is encumbered.

The tables, placed at the beginning of these notes, indicate the mutual relations of the principal eruptive rocks. *Above* the name of each rock, symbols are placed, denoting its essential constituents. The symbol consists in most cases of the first three letters of the name of the mineral. In a few instances but one letter is used, sometimes with, at others without smaller qualifying letters or symbols. This plan of abbreviating the names is so simple that the meaning of each symbol is at once apparent; but, to prevent

possible mistakes, the tables are preceded by an index, giving the names in full.

After the tables, come definitions of the terms used to denote the most important microscopic structures. These are succeeded by notes on the mineral constitution of the eruptive rocks, and here lists of the accessory and secondary minerals are given.

The tables showing the classification of the eruptive rocks are divided by horizontal lines into three zones, the volcanic rocks, or lavas, being placed in the uppermost, the dyke-rocks in the middle, and the plutonic rocks in the lowest zone. It should, however, be remembered that there is, in reality, no sharp demarcation between these rocks. On the contrary, the dykes may, in a certain sense, be regarded as constituting a connection between the plutonic masses and their volcanic representatives.* The names of altered and pyroclastic rocks are printed in italics.

The notes on mineral constitution are followed by a series of determinative tables, which differ in some respects from those hitherto published, being to a certain extent simplified, in order to meet the general requirements of students. Chemical formulæ and specific gravities are not given, since they can be found in any good text-book of mineralogy, and the tables are cleared, as far as possible, of matter which does not relate to simple microscopic investigation. Explanatory notes precede the tables, which are accompanied by an index, reference to the latter at once showing upon which table the required mineral will be found. The notes are necessarily brief.

For further information, the student may be referred to Teall's *British Petrography*, and to the works of Lévy and Lacroix, Rosenbusch, Zirkel, v. Lasaulx, Kalkowsky, Gümbel and Jannettaz.

* Veins, dykes and the infillings of volcanic fissures and pipes appear, indeed, to be merely progressive phases of vertical intrusion, while sills may be looked upon as the homologues of lava-flows, especially of those from fissure-eruptions, and laccolites as those of domes. In the latter case the homology is supported by the circumstance that both laccolites and domes are, as a rule, formed from highly viscous magmas which solidified as trachyte, while those sills which are intruded for long distances are generally basic in composition. The difference of the conditions under which on the one hand lava-flows and domes, on the other sills and laccolites are formed, is a sufficient reason why the latter are unaccompanied by tuffs, since the explosions of steam necessary for their production could not take place under the pressure of a great thickness of overlying rock.

TABULAR CLASSIFICATION

OF

ERUPTIVE ROCKS,

THE ESSENTIAL CONSTITUENTS BEING DENOTED BY SYMBOLS.

INDEX OF SYMBOLS.

Arf.	Arfvedsonite.
Aug.	Augite.
Bio.	Biotite.
Bro.	Bronzite.
Can.	Cancrinite.
Chro.	Chromite.
Cos.	Cossyrite.
Dia.	Diallage.
Ens.	Enstatite.
Eud.	Eudialyte.
Fel.	Felsitic, Microfelsitic, Microcrystalline or Cryptocrystalline-groundmass.
Gar.	Garnet.
Gran.	Granular groundmass.
Haüy.	Haüyne.
Hor.	Hornblende.
Hyp.	Hypersthene.
Lep.	Lepidolite.
Leu.	Leucite.
Mag.	Magnetite.
Melan.	Melanite.
Melil.	Melilite.
Micro.	Microcline.
Mus.	Muscovite.
Nep.	Nepheline.
$\overline{\text{N}}$.	Nepheline (decomposition products after).
N^{E}.	Elæolite.
O.	Orthoclase.
O^{A}.	Anorthoclase.
O^{S}.	Sanidine.
Oliv.	Olivine.
Omp.	Omphacite.
P.	Plagioclase.
$\overset{\text{Alb.}}{\text{P}}$.	Albite.
$\overset{\text{Ano.}}{\text{P}}$.	Anorthite.
Pero.	Perowskite.
Pic.	Picotite.
Q.	Quartz.
Serp.	Serpentine.
Sma.	Smaragdite.
Sod.	Sodalite.
Vit.	Vitreous matter.

A symbol in italics indicates either a groundmass or else residual, interstitial matter.

A line over a symbol indicates that the mineral is partly or wholly represented by decomposition products.

When a mineral is only present in small quantity, its symbol is given without a capital, *e.g.* bio. = Biotite, in small quantity.

For accessory and secondary constituents see p. 15 *et seq.*

ULTRA-BASIC SERIES. TABLE A.

Silica = 39 to 45 %

NON-FELSPATHIC.

	PYROXENITE GROUP.			PERIDOTITE GROUP.				
Volcanic Rocks.							*Picrite-porphyrites.* *Kimberlite.*	p. 25.
Dykes and Sills.							*Peridotite Dykes.*	p. 25.
				Serpentines.				
Plutonic Rocks.	Hor. Aug. HORNBLENDITE Sma. Omp. Gar. ECLOGITE	Hyp. HYPERSTHENITE Bro. BRONZITITE Ens. Dia. WEBSTERITE Dia. DIALLAGITE		Oliv. Aug. PICRITE Oliv. Hor. HORNBLENDE-PICRITE	Oliv. Dia. WEHRLITE Oliv. Aug. Gar. EULYSITE	Oliv. Dia. Bro. Pic. LHERZOLITE Oliv. Hor. Hyp. CORTLANDITE Oliv. Bro. SAXONITE Oliv. Chro. DUNITE	Serp. Bio. Pero. MICA-PERIDOTITE Serp. Hor. Mica. SCYELITE	p. 23.

Serpentines, p. 25.

BASIC SERIES.

TABLE B.

Silica=45 to 55 %

WITH

NON-FELSPATHIC but potentially felspathic, nephelitic or leucitic, when not actually so (see p. 20).		PLAGIOCLASTIC FELSPARS. NEPHELINE SERIES.	PLAGIOCLASTIC FELSPARS.						
			Basalt Tuffs. *BASALT GROUP.*						p. 20.
	Aug. Mag. *Vit.* AUGITITE				*Palagonite* HYALO-BASALT				
	Oliv. Aug. Mag. *Vit.* LIMBURGITE	P. Leu. Aug. LEUCITE-TEPHRITE	*Melaphyres.*						
Leu. Aug. LEUCITITE	Nep. Aug. NEPHELINITE	P. Nep. Aug. TEPHRITE							
Leu. Aug. Oliv. LEUCITE-BASALT	Nep. Aug. Oliv. NEPHELINE-BASALT	P. Nep. Aug. Oliv. BASANITE	P. Aug. Oliv. OLIVINE-BASALT	P. Aug. Hor. HORNBLENDE-BASALT	P. Aug. BASALT	P. Aug. Oliv. Hyp. *Vit.* HYPERSTHENE-BASALT	P. Aug. Bio. MICA-BASALT	P. Q. Oliv. Aug. QUARTZ-BASALT	
Melil. Aug. MELILITE-BASALT									
			DOLERITE GROUP. *Ophites, Epidiorites, Diabases.*						p. 21.
	Aug. Hor. Bio. *Vit.* FOURCHITE				TACHYLYTE				
					P. aug. q. LEUCOPHYRE				
Melil. Mag. Bio. Oliv. Aug. ALNÖITE	Aug. Hor. Bio. Oliv. *Vit.* MONCHIQUITE		P. Aug. Oliv. OLIVINE-DOLERITE	P. Aug. Hor. HORNBLENDE-DOLERITE or PROTEROBASE	P. Aug. DOLERITE	P. Aug. Ens. ENSTATITE-DOLERITE	P. Aug. Bio. MICA-DOLERITE		
			GABBRO GROUP. *Euphotides.*						p. 22.
	Nep. hor.(or bio.) IJOLITE	P. Nep. Aug. THERALITE	P. Aug. Hor. Oliv. OLIVINE-GABBRO	P. Aug. Hor. HORNBLENDE-GABBRO	P. Aug. GABBRO	P. Hyp. (or Ens.) NORITE		P. Hyp. Q. QUARTZ-NORITE	
			P. Oliv. TROCTOLITE	P. Aug. Hor. Bio. TESCHENITE	Ano. P. Aug. EUCRITE	P. Hyp. (or Ens.) Oliv. OLIVINE-NORITE			

Melaphyres, p. 24. *Diabases*, p. 24. *Ophites*, p. 25. *Epidiorites*, p. 25. *Euphotides*, p. 25.

INTERMEDIATE SERIES. TABLE C.

Silica=55 to 66 %

WITH

PLAGIOCLASTIC FELSPARS.

NEPHELINE SERIES.						
	Andesite Tuffs.					
	ANDESITE GROUP.					p. 18.
P. Hor. Aug. Haüy (nep ?) HAÜYNE-ANDESITE		*Palagonite* HYALO-ANDESITE			HYALO-DACITE	
	Propylites.					
	Porphyrites.					
	P. Hor. *Vit.* HORNBLENDE-ANDESITE	P. Aug. *Vit.* AUGITE-ANDESITE	P. Hyp. *Vit.* HYPERSTHENE-ANDESITE	P. Bio. *Vit.* MICA-ANDESITE	P. Hor. Q. *Vit.* DACITE	
				LAMPROPHYRE GROUP.		p. 19.
				P. Bio. KERSANTITE		
				P. Aug. Hor. Bio. *Vit.* CAMPTONITE	P. Bio. Hor. Q. *Gran.* MALCHITE	
	DIORITE GROUP.					p. 19.
Alb. P. Nep. LITCHFIELDITE	P. Hor. DIORITE	P. Aug. AUGITE-DIORITE	P. Ens. ENSTATITE-DIORITE	P. Bio. MICA-DIORITE	P. Hor. Q. QUARTZ-DIORITE	
	Ano. P. Hor. CORSITE				P. Hor. Bio. Q. TONALITE	

Porphyrites, p. 24. *Propylites*, p. 24.

INTERMEDIATE SERIES. TABLE D.

Silica=55 to 66 %

WITH

ORTHOCLASTIC FELSPARS.

NEPHELINE SERIES.					
Haüyne and Nosean often present.	*Trachyte Tuffs.* *TRACHYTE GROUP.* (The felspars are the dominant constituents. Plagioclase, usually Oligoclase, present. Groundmass often microlitic.)				p. 17.
HYALO-PHONOLITE		HYALO-TRACHYTE			
O^{s} Nep. Aug. *Vit.* PHONOLITE					
O^{s} Leu. Aug. *Vit.* LEUCITE-PHONOLITE					
O^{s} Leu. Nep. Aug. *Vit.* LEUCITOPHYRE	O^{s} Hor. *Fel.* HORNBLENDE-TRACHYTE	O^{s} Aug. *Fel.* AUGITE-TRACHYTE	O^{s} Bio. *Fel.* MICA-TRACHYTE	O^{A} Aug. Cos. *Vit.* PANTELLERITE	
	LAMPROPHYRE GROUP.				
	O. Bio. Hor. HORNBLENDE-MINETTE	O. Bio. Aug. AUGITE-MINETTE	O. Bio. MINETTE		p. 17.
O. $\overline{\text{Nep.}}$ Aug. Bio. Melan. BOROLANITE	O. Hor. HORNBLENDE-VOGESITE	O. Aug. AUGITE-VOGESITE			
O. N^{e} Aeg. *Gran.* TINGUAITE				O. O^{A} Q. BOSTONITE	
O. N^{e} Aug. FOYAITE	*SYENITE GROUP.* (Plagioclase generally present, except in augite-syenites containing anorthoclase.)				
O. N^{e} Hor. ELŒOLITE-SYENITE	O. Hor. Bio. SYENITE	O. Aug. Bio. AUGITE-SYENITE	O. Bio. MICA-SYENITE		p. 17.
O. N^{e} Hor. Zir. ZIRCON-SYENITE					
O. N^{e} Can. Sod. Hor. DITROITE					
O. N^{e} Arf. Sod. Eud. EUDIALYTE-SYENITE					
O. N^{e} Bio. Q. MIASCITE					

ACID SERIES. TABLE E.

Silica=over 66 %

Felspars mostly plagioclase or anorthoclase.	WITH ORTHOCLASTIC FELSPARS.					
	Rhyolite Tuffs, Pumice. *RHYOLITE GROUP.* (Plagioclase often present.)					
Alb. P. Q. *Fel. & Vit.* SODA-RHYOLITE O^s P. Q. hor. *Vit. & Fel.* DACITE pt. O^A Aug. Cos. *Vit.* PANTELLERITE pt.					*Felsite pt.* HYALO-RHYOLITE including OBSIDIAN, PERLITIC OBSIDIAN and PITCHSTONE O^s Q. *Fel. & Vit.* RHYOLITE or LIPARITE	p. 15
	ELVAN GROUP.					
P. *Fel.* KERATOPHYRE P. Q. *Fel.* QUARTZ-KERATOPHYRE					PITCHSTONE DYKES O. *Fel.* FELSPAR-PORPHYRY O. Q. Felsite pt. MICRO-GRANITE HAPLITE O. Q. Mus. PEGMATITE O. Q. mus. bio. *Fel.* QUARTZ-FELSITE or QUARTZ-PORPHYRY	p. 16.
	GRANITE GROUP. (Plagioclase almost always present. Microcline frequent.)					
	O. Q. Hor. Bio. HORNBLENDE-GRANITE	O. Q. Aug. Bio. AUGITE-GRANITE	Micro. Q. Hyp. HYPERSTHENE-GRANITE		*Arkose.* *Kaolin.* O. Q. Mus. Bio. GRANITE O. Q. Mus. MUSCOVITE-GRANITE O. Q. Bio. BIOTITE-GRANITE or GRANITITE	p. 16.

Felsites, p. 24. *Arkose*, p. 24.

STRUCTURES DEFINED

Idiomorphic. When the mineral constituents of a rock have attained the condition of fully developed crystals.

Allotriomorphic. When the minerals occur in crystalline grains and not in perfectly formed crystals.

Panidiomorphic. When all the constituents of a rock are idiomorphic.

Hypidiomorphic. When some of the constituents are idiomorphic while others are allotriomorphic.

Porphyritic. When some of the crystals are idiomorphic, while others have crystallised subsequently in a more rapid manner, less perfectly, or on a much smaller scale; or when the residue of the magma has solidified as glass, the larger idiomorphic crystals are said to occur porphyritically. Such crystals have been termed "phenocrysts" by Prof. Iddings.

Groundmass. That portion of a rock which constitutes the matrix in which porphyritic crystals are embedded.

Microlitic. When the groundmass consists of minute crystalline bodies or microlites.

Microcrystalline. When a rock, or the groundmass of a rock, consists of an aggregate of very diminutive, allotriomorphic, crystalline grains, the boundaries of which are recognisable under the microscope.

Cryptocrystalline. When the minute allotriomorphic grains constituting a rock, or its groundmass, show no distinct boundaries under the microscope but appear to run irregularly one into another.

Glassy base. The residual portion of a magma which has solidified rapidly as glass, constituting a vitreous groundmass, in which a variable quantity of microscopic bodies (microlites, trichites, globulites, etc.) have usually been developed. The vitreous matter in some rocks may be very small in amount, in others it may constitute the entire rock.

Devitrification. The change caused by the development of crystalline structure in vitreous matter. A glassy rock when devitrified loses its glassy lustre and translucence, thus an obsidian may, through devitrification, assume a lithoidal character and pass into a felsite. The change may result from the development of globulites or trichites, or from the setting up of a microcrystalline or cryptocrystalline structure, and occasionally, to some extent, from the formation of spherulites.

Perlitic. Essentially vitreous lavas and dykes frequently show what is termed perlitic structure, which consists in the development of small, very commonly microscopic, ellipsoidal or spheroidal cracks which are seldom quite continuous, but die out and are succeeded by others, the general arrangement being rudely concentric. These perlitic cracks are usually packed between irregularly-disposed rectilinear cracks.

Microfelsitic. This term is applied to a substance which in some respects closely resembles vitreous matter, but differs from it in being less translucent and in consisting of hazily-defined scales and fibres. When these are irregularly disposed the microfelsitic substance exerts no appreciable action upon polarised light and appears to be isotropic, but when there is either a parallel or a radial arrangement of the fibres the substance exhibits feeble double refraction.

Felsitic. A micro- or crypto-crystalline aggregate of quartz and felspar is known as felsitic matter. The terms felsitic and microfelsitic have, therefore, widely different significations. The symbol *Fel.* employed in these tables includes, however, both felsitic and microfelsitic matter.

Hyalopilitic is a term applied to the vitreous matter of a groundmass, when in great part filled with or replaced by diminutive crystals or microlites, which form a more or less densely felted mass.

Pilotaxitic is applied to the felted structure above described, when no vitreous matter is present. Pilotaxitic structure is by no means rare in some of the basalts and melaphyres.

Ophitic. When a crystal of one mineral is penetrated in different directions by elongated or lath-shaped crystals of another mineral (*e.g.* augite penetrated by felspars). The penetrated crystal thus appears to be broken up into a number of irregularly shaped and detached pieces, but these are seen in polarised light to be parts of the same crystal since they undergo simultaneous extinction.

Glomero-porphyritic. When a rock is rendered porphyritic by crystalline-granular aggregates.

Granular. Composed of irregularly-shaped crystalline grains, as in granites. In sedimentary rocks the grains are usually more or less rounded, as in sandstones, etc.

Fluxion Structure is shown either by approximately parallel streams of microlites or by differences in texture, sometimes in colour, of the vitreous or other matter of which the rock is composed. When porphyritic crystals are present the streams are seen to sweep around them. Occasionally the fluxion-banding appears much contorted, like the mottling on a Damascus blade. These structures are common in rhyolites.

Migration Structure resembles fluxion structure, but is assumed to result from the decomposition of original constituent minerals, and the migration and recrystallisation of the products in fresh positions.

Miarolitic Structure. When small, irregular cavities occur into which the constituent crystals of the rock project.

Spherulitic Structure consists in the development of spherical or approximately spherical bodies, usually, but not always, consisting of radiating crystalline fibres, sometimes with interstitial glassy or microfelsitic matter. Much elongated spherulitic bodies are termed *axiolites.* The large, hollow, spherulitic bodies occurring in obsidians, felsites, and rhyolites are called *lithophyses.*

Spheroidal Structure appears to originate in several ways: (1) from weathering, blocks of rock bounded by intersecting joint planes becoming rounded more and more as decomposition proceeds; (2) from mineral segregation; (3) from contraction.

Columnar Structure results from the contraction of a rock-mass on cooling. The shrinkage planes or joints, which by their intersection give rise to polygonal columns, are traversed by cross joints, and between these intersecting joint planes spheroidal structure is frequently developed.

Platy Structure. A few eruptive rocks, notably phonolites, have contracted on cooling in such a manner that they have become traversed by a series of parallel and often but slightly separated joints, so that the rock may be readily split into slabs. The phonolite of the Tuillière, near Mont Dore, Auvergne, affords a good example of this structure, the slabs when quarried being sufficiently thin for roofing purposes.

Holocrystalline. When a rock consists wholly of crystalline matter.

Hypocrystalline. When vitreous or microfelsitic matter is associated with the crystalline material of a rock.

Since the crystalline schists are not treated of in these notes, such terms as *mylonitic structure, flaser structure*, etc., are not defined.

MINERAL CONSTITUTION DEFINED.

ABBREVIATIONS:
Ess. Con. = Essential constituents.
Acc. Con. = Accessory constituents.
Sec. Con. = Secondary constituents.

1. RHYOLITE GROUP.

OBSIDIANS. Essentially vitreous rocks, containing either no water or generally less than 3 per cent. Crystallites present, often in profusion. Sometimes with porphyritic crystals or with microlites of sanidine, biotite, augite, etc. Gas inclusions frequently present.

PUMICE. A frothy or vesicular condition of obsidian or of any vitreous rock, due to the inclusion of gas or steam in bubbles, which are usually drawn out into thread-like cavities or tubes.

PERLITIC OBSIDIANS contain from 1 to 3 per cent. of water. Lustre vitreous, occasionally enamel-like. Perlitic structure present, also banding or fluxion structure, streams of microlites and spherulites either isolated or coalescing in bands.

PITCHSTONES. From 3 to over 9 per cent. of water usually present. Often densely packed with microlites. Frequently porphyritic with sanidine, quartz, plagioclase, etc. Augite, hornblende, and magnetite frequently present. Perlitic and spherulitic structures common.*

Felsites (Hälleflinta, Felstone, Petrosilex, Eurite pt.). Obsidians and pitchstones which have undergone alteration from a vitreous to a lithoidal condition. The obsidians and pitchstones of the Archæan, Cambrian and Silurian periods are commonly met with in this devitrified state. The change is due to the development of a crypto-crystalline or micro-crystalline structure in the once vitreous material. It does not, however, as a rule, suffice to mask perlitic and other structures which these rocks may have originally possessed. Epidote sometimes present.

Felsites are not exclusively devitrified rocks, in some cases they occur as dykes and then approximate to the micro-granites or granophyres, but all felsites are, if the felspar be orthoclase, essentially crypto-crystalline or micro-crystalline aggregates of that mineral and quartz.

SODA-FELSITES (Keratophyres, Eurites pt.) differ from the preceding in the felspathic constituent being partly or wholly a felspar rich in soda. Augite, horn-

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* Pitchstones occasionally occur as flows, but commonly as dykes. In the latter case they may be referred to the Elvan Group.

blende, biotite, etc., sometimes present. The keratophyres approximate to fine-grained granitic and syenitic rocks. In the latter case they may be regarded as felsites of the trachyte group.

RHYOLITES. Highly acid lavas, generally with a porphyritic structure. Crystals of sanidine and quartz in a microfelsitic groundmass, often with a variable amount of vitreous matter.

Acc. Con. Oligoclase, biotite, hornblende, augite, apatite, sphene, dichroite, garnet, orthite, magnetite, specular-iron, tridymite.

Sec. Con. Chlorite, epidote, pyrites, calcite, quartz, chalcedony, opal. The rhyolites commonly show fluxion- and spherulitic-structures. The pyromerides are coarsely spherulitic rhyolites.

SODA-RHYOLITES differ from the ordinary or potash rhyolites in the felspar being oligoclase, soda-microcline or albite. They form a connecting link between the rhyolites and the pantellerites.

PANTELLERITES consist of a groundmass (often partly vitreous) of felspar and augite, with porphyritic crystals of anorthoclase, augite and cossyrite (triclinic hornblende). They form a link between the soda-rhyolites and the dacites.

2. ELVAN GROUP (Apophyses of deep-seated granitic masses).

PITCHSTONE DYKES (*see* p. 15).

MICROGRANITES. Fine crystalline aggregates of quartz and felspar with little or no mica. In the latter case they approximate to felsites. Garnet, schorl, etc., sometimes present.

HAPLITES (Aplites). Similar to the preceding; poor in mica, not porphyritic.

QUARTZ-PORPHYRIES (Quartz-felsite). Porphyritic crystals of quartz, sometimes also of orthoclase, in a micro-crystalline or crypto-crystalline groundmass of quartz and felspar. A little mica often present, also schorl. At times the groundmass is micro-pegmatitic, and when this is the case the rock is sometimes termed GRANOPHYRE.

Rosenbusch, mainly adopting Vogelsang's classification, divides the rocks which he includes under the head of Quartz-porphyry into Microgranite and Granophyre (with crystalline granular groundmass), Felsophyre (with felsitic groundmass), and Vitrophyre (with vitreous groundmass), the Felsophyres embracing devitrified rhyolites, pitchstones, and obsidians, and the Vitrophyres including pitchstones in their comparatively unaltered condition.

FELSPAR-PORPHYRIES. The only porphyritic constituent is felspar in a micro- or crypto-crystalline groundmass of quartz and felspar.

PEGMATITE. Coarsely crystalline granite occurring in segregation-veins. Graphic granite is a variety in which the felspar and quartz form a regular intergrowth, the two minerals having a definite mutual crystallographic orientation. Micro-pegmatite is a similar arrangement of quartz and felspar on a purely microscopic scale.

GREISEN. Essential constituents quartz and mica, usually a lithia mica. Topaz and tinstone often present. The *stockwerksporphyr* of German miners contains black mica and more or less chlorite. Accession of orthoclase causes greisen to pass over into granite.

3. GRANITE GROUP (Holocrystalline-granular rocks).

GRANITES. *Ess. Con.* Orthoclase (often microcline, almost invariably some plagioclase), mica (muscovite, biotite), quartz.

Acc. Con. Apatite, sphene, zircon, schorl, topaz, andalusite, dichroite, garnet, orthite, triphyline, monazite, pyrites, tinstone, wolfram, oligoclase, magnetite, ilmenite. In those granites which carry tinstone, schorl and topaz are very generally present.

Sec. Con. Chlorite, epidote, calcite, talc, kaolin, hematite.

Typical or NORMAL GRANITE contains both muscovite and biotite. In BIOTITE-GRANITE or GRANITITE the only mica is biotite. Other micas, *e.g.* lepidolite, lepidomelane, etc., are sometimes present in granites. HORNBLENDE-GRANITES contain black or green hornblende; AUGITE-GRANITES, pale green augite (malacolite).

HYPERSTHENE-GRANITE, consisting of potash felspar, chiefly microcline, hypersthene, blue quartz, and a small amount of garnet, has been found by Mr. T. H. Holland in the Madras Presidency. He proposes the name CHARNOCKITE for this rock.

4. TRACHYTE GROUP.

HYALO-TRACHYTES. Vitreous rocks, of restricted occurrence, with porphyritic crystals of sanidine, augite, and biotite. Glass generally brown or yellow, sometimes assuming a microfelsitic character. Magnetite usually present.

TRACHYTES. Holocrystalline-porphyritic or hypocrystalline-porphyritic rocks with microlitic, sometimes partly vitreous groundmass. The latter generally consists, however, of microlites of sanidine. Hornblende, augite (malacolite), bronzite, hypersthene or biotite may be present.

Acc. Con. Apatite, sphene, zircon, dichroite, haüyne, nosean, olivine, spinel, låvenite, rinkite, quartz, tridymite, magnetite, ilmenite.

Sec. Con. Chlorite, alunite, chalcedony, hyalite, opal, pyrites. In HORNBLENDE-TRACHYTES the amphibole may be ordinary green hornblende or actinolite. In AUGITE-TRACHYTES the pyroxene may be malacolite or the soda varieties, acmite and aegirine. The MICA-TRACHYTES contain biotite.

The trachytes are characterised by presence of sanidine and absence of quartz. When quartz is present the rocks approximate to rhyolites.

5. LAMPROPHYRE GROUP (in part). This group embraces the rocks generally known as mica-traps, including the minettes (related to the mica syenites), the kersantites (related to the mica-diorites), and the vogesites.

MINETTES. Essentially dyke-rocks of holocrystalline-porphyritic character, consisting mainly of orthoclase and biotite. The felspar is sometimes partly plagioclastic, as in some of the mica traps of Westmorland, in which case the rock occupies a position between minette and kersantite.

HORNBLENDE VOGESITES consist of orthoclase and hornblende.

AUGITE VOGESITES consist of orthoclase and augite. These rocks also contain magnetite, apatite, epidote, chlorite, calcite, and occasionally a little biotite and olivine. In structure the vogesites are granular and sometimes porphyritic.

BOSTONITES are dyke-rocks of holocrystalline-porphyritic character, consisting of orthoclase, anorthoclase, and quartz in a groundmass composed of small lath-shaped crystals of orthoclase. These dykes occur chiefly in the Lake Champlain district between New York and Vermont, U.S.A., and also near Montreal in Canada, where they are associated with elæolite syenites.

6. SYENITE GROUP (Holocrystalline-granular or porphyritic rocks).

SYENITE (Hornblende-syenite) is essentially composed of orthoclase and hornblende; AUGITE-SYENITE of orthoclase and augite; and MICA-SYENITE of orthoclase and biotite.

Acc. Con. Oligoclase, apatite, sphene, zircon, magnetite, ilmenite, rutile.
Sec. Con. Chlorite, talc, epidote, calcite, kaolin, hematite.

True syenites contain no quartz, or but a very small amount. An increase in quartz causes these rocks to pass over into granites.

7. TRACHYTE GROUP (NEPHELINE SERIES).

Hyalo-Phonolites. Vitreous rocks of rare occurrence. They occasionally form crusts on phonolite lavas, as in the Canary Isles.

Phonolites. Holocrystalline- or hypocrystalline-porphyritic rocks. The porphyritic constituents are sanidine, nepheline, or leucite with pyroxene (either malacolite or aegirine). The groundmass is mostly holocrystalline and composed of the above minerals, but it is sometimes hypocrystalline or vitreous. Nepheline and leucite may both be present.

Acc. Con. Hornblende, biotite, sodalite, haüyne, nosean, melanite, spinel, olivine, wollastonite, tridymite.
Sec. Con. Natrolite, analcime, diaspore, muscovite, chlorite, kaolin, quartz.

8. SYENITE GROUP (DYKE-ROCKS OF THE NEPHELINE SERIES).

Borolanite. *Ess. Con.* Orthoclase, decomposition products after nepheline, melanite, augite and biotite. Occurs at Loch Borolan in Sutherlandshire.

Tinguaite. *Ess. Con.* Orthoclase, elæolite, and aegirine in a crystalline-granular groundmass of the same minerals. Låvenite and rinkite usually present. Chiefly met with in Portugal and Brazil.

9. SYENITE GROUP (NEPHELINE SERIES).

The rocks of this series are holocrystalline-granular or porphyritic. They consist of orthoclase and elæolite, with one or more of the following minerals: augite, hornblende, arfvedsonite, biotite, zircon, sodalite, eudialyte, (cancrinite, which may replace elæolite).

Acc. Con. Sphene, apatite, magnetite, ilmenite.
Sec. Con. Natrolite, calcite, rutile, anatase, limonite.
Foyaite. *Ess. Con.* Orthoclase, elæolite and augite.
Elæolite Syenite. „ „ and hornblende.
Zircon Syenite. „ „ hornblende and zircon.
Ditroite. „ cancrinite, hornblende, and sodalite.
Eudialyte Syenite. „ elæolite, arfvedsonite, sodalite, eudialyte.
Miascite. „ „ biotite and quartz.

10. ANDESITE GROUP.

Hyalo-Dacites differ from the vitreous rocks of the rhyolite group in containing oligoclase or andesine instead of sanidine. Small crystals of biotite, hornblende, or augite and quartz occur in a yellowish or brownish glass, often devitrified by globulites. Spherulitic growths not uncommon.

Dacites (Quartz-andesites) consist of a groundmass which may be a holocrystalline aggregate of felspar and quartz, or it may be microfelsitic, or, again, it may be composed of small crystals or microlites of felspar with a certain amount of vitreous matter, in which case the microlites lie with their longest axes in the

direction of flow. In one or other of such groundmasses porphyritic crystals of plagioclase (generally andesine or labradorite), biotite, hornblende and quartz occur. Augite and enstatite sometimes present.

HYALO-ANDESITES. The main difference between these rocks and the hyalo-trachytes is in the nature of the felspar and in the chemical composition of the glass. There are andesite-pitchstones, andesite-obsidians, and andesite-pumice.

Variolites are devitrified, coarsely-spherulitic hyalo-andesites.

ANDESITES. Holocrystalline or hypocrystalline-porphyritic rocks. The groundmass may be microlitic, microfelsitic or cryptocrystalline, sometimes partly vitreous, at others wholly so. A hyalopilitic groundmass is of common occurrence. As a rule the groundmass contains more or less vitreous matter. The porphyritic minerals are plagioclase and a ferro-magnesian silicate. Oligoclase, andesine, and labradorite generally occur in the hornblende-andesites and mica-andesites, while bytownite and anorthite are most common in the augite- and enstatite-andesites. The essential constituents of the different varieties are shown on the Table, p. 10.

Acc. Con. Apatite, zircon, sphene, garnet, dichroite, olivine, orthite, magnetite, ilmenite, specular-iron, tridymite.

Sec. Con. Chlorite, epidote, kaolin, muscovite, leucoxene, calcite, aragonite, chalybite, chalcedony, opal, alunite, limonite, pyrites.

11. LAMPROPHYRE GROUP (in part).

KERSANTITES differ from minettes in the felspar being chiefly plagioclastic. In addition to biotite, they sometimes contain augite or hornblende.

Acc. Con. Orthoclase, quartz, sphene, ilmenite, magnetite, apatite, olivine, pyrites.

Sec. Con. Talc, chlorite, epidote, calcite, uralite.

CAMPTONITES consist of plagioclase, hornblende, augite, and a little biotite, often with a small amount of vitreous matter.

Acc. Con. Apatite, ilmenite, magnetite.

Sec. Con. Chlorite, delessite, analcime, calcite.

Camptonite dykes occur in New Hampshire, U.S.A., and near Montreal.

MALCHITE occurs as dykes in the Odenwald, Germany. The groundmass consists of labradorite, hornblende, and quartz, forming a granular aggregate, in which porphyritic crystals of biotite, labradorite, and quartz occur rather sparsely.

12. DIORITE GROUP. Holocrystalline-granular rocks consisting essentially of a plagioclastic felspar (of any species from oligoclase to anorthite) and a ferro-magnesian silicate which in NORMAL DIORITES is hornblende; in AUGITE DIORITES, pale-green augite; in ENSTATITE DIORITES, enstatite; and in MICA DIORITES, biotite. There are also quartz-diorites, quartz-augite diorites, and quartz-enstatite diorites. TONALITE is a quartz-mica diorite. The CORSITES are those diorites in which the felspar is anorthite.

Acc. Con. Biotite, zircon, sphene, garnet, hypersthene, spinel, apatite, orthite, quartz, magnetite, ilmenite.

Sec. Con. Chlorite, epidote, actinolite, uralite, calcite, quartz.

13. ANDESITE GROUP (NEPHELINE SERIES). The existence of a nepheline-bearing series of andesites is, as yet, scarcely established, but it is rendered probable by the occurrence of haüyne-andesites in the Canary Islands, Nassau, and elsewhere. Sauer considered that a little nepheline was present in the Canary Islands andesites.

Haüyne-Andesites consist of plagioclase, hornblende, augite, haüyne, sphene, magnetite, apatite, and a little zircon in a hyalo-pilitic groundmass, consisting of plagioclase, augite, magnetite, and vitreous matter crowded with opaque crystallites and trichites. Rosenbusch regards these rocks as closely related to the nepheline-tephrites.

Litchfieldite, consisting essentially of nepheline and albite, may be regarded as a plutonic representative of the nepheline series of andesites. Rocks of similar composition, but containing in addition biotite, hornblende, sodalite, calcite, etc., occur in Ontario, Canada.

14. BASALT GROUP.

Hyalo-Basalts. These basic vitreous rocks, known as tachylyte, hyalomelane, etc., are not of very common occurrence, nor do they ever constitute independent rock-masses, but occur either as crusts on the surfaces of lavas, or as selvages to the margins of dykes, and seldom, in the one case or the other, do they generally exceed one or two inches in thickness. The basalt-glass of the Sandwich Islands is often quite spongy in texture, owing to the numerous vesicles which it contains. These are due to the expansion of aqueous vapour during the solidification of the lava, and the thin glassy walls of such vesicles, becoming drawn out in cobweb-like threads, constitute the well-known "Pélé's hair" of these volcanoes. Sometimes the basalt-glass is but slightly, if at all, vesicular, and forms a thin, slaggy crust on the lava. Small crystals of olivine and felspar are usually present, the former often in delicate skeleton crystals of the chiasmolitic type. The tachylytes forming the selvages of dykes are mostly of dull black or dark brown colour, and nearly opaque, owing to separation of magnetite. They are frequently spherulitic. They pass by decomposition into yellow, brown, or greenish palagonite.

Basalts. Holocrystalline-porphyritic to hypocrystalline-porphyritic basic rocks, frequently ophitic. Groundmass sometimes partly, occasionally wholly, vitreous.

Ess. Con. A plagioclastic felspar, generally labradorite or anorthite, with (in normal basalts, augite), (in olivine basalt, augite and olivine), (in hornblende basalt, augite and hornblende), (in mica-basalt, augite and biotite), (in quartz-basalt, augite, olivine, and quartz). Hypersthene-basalts consist essentially of plagioclase, augite, olivine, and hypersthene, with a large amount of dark-brown vitreous matter forming the groundmass, to which numerous microlites of plagioclase and augite impart an almost hyalo-pilitic character. The hypersthene-basalts form a connecting link between the basalts and andesites. They occur chiefly in Oregon, U.S., and Salvador, Central America.

Acc. Con. Apatite, zircon, bronzite, magnetite, ilmenite, native-iron, specular-iron, pseudobrookite, rutile, perowskite, and occasionally tridymite and graphite.

Sec. Con. Chlorite, delessite, chlorophæite, epidote, calcite, aragonite, chalybite, leucoxene, serpentine, kaolin, muscovite, quartz, chalcedony, and zeolites.

15. BASALT GROUP (NEPHELINE SERIES).

This series may be separated into two divisions. In the first, both felspar and nepheline are present. In the second division, felspar is absent, and nepheline is not present in all cases. Nevertheless, the rocks of this division may be regarded as *potentially* felspathic, leucitic or nepheline-bearing, since the chemical composition of the vitreous matter which often forms their groundmass is such as to warrant

the conclusion that, under suitable conditions, plagioclastic felspars, leucite and nepheline would have crystallised out.

1. *Felspathic Division.* (Headed "NEPHELINE SERIES" in Table, p. 9.)

TEPHRITES consist essentially of a basic lime-soda plagioclase with nepheline or leucite and augite (basaltic augite), and in some cases glassy matter, which in certain Vesuvian tephrites is sufficient to impart a strongly vitreous aspect.

BASANITES differ from tephrites in containing olivine in addition to the other constituents. In the tephrites and basanites the nepheline may be replaced by leucite, or both minerals may be present.

Acc. Con. Aegirine, hornblende, biotite, haüyne.

These rocks are related, not only to the basalts and non-felspathic rocks of the basalt group, but also to the phonolites.

2. *Non-felspathic Division.* (Headed "NON-FELSPATHIC" in Table, p. 9.)

NEPHELINITE. Essential constituents, nepheline and augite.

Acc. Con. Apatite, sphene, haüyne, melanite, biotite, hornblende, aegirine, magnetite, ilmenite.

NEPHELINE-BASALT differs only from nephelinite in containing olivine. The nephelinites and nepheline-basalts are for the most part holocrystalline-porphyritic.

LEUCITITE differs from nephelinite in containing leucite instead of nepheline.

LEUCITE-BASALT differs from nepheline-basalt in containing leucite instead of nepheline.

MELILITE-BASALT consists essentially of melilite and augite. A glassy basis has in some cases been noted.

Acc. Con. Olivine, biotite, apatite, chromite, perowskite, picotite, magnetite. Sometimes haüyne and nepheline.

Melilite-basalt is closely related to alnöite.

AUGITITE consists essentially of augite and magnetite, the former occurring in crystals and microlites, the latter in a granular condition, or in the form of trichites embedded in a vitreous base. Ilmenite and apatite almost always present.

Acc. Con. (occasionally in small quantity). Plagioclase, nepheline, leucite, haüyne, sphene, perowskite and chromite. In some cases the augite may, to a limited extent, be represented by hornblende.

LIMBURGITE merely differs from augitite in containing olivine. The augitites and limburgites were included by Bořicky under the title "Magma Basalt."

16. DOLERITE GROUP (Diabase of Continental writers). Holocrystalline-granular basic rocks, occurring not only as dykes and intrusive sheets or sills, but passing upward into the basalts, so that they must, at times, be in part regarded as truly volcanic rocks. Lower portions of basalt lava-streams often doleritic in character. Ophitic structure common, also frequently porphyritic and amygdaloidal. Vitreous matter generally absent, never plentiful.

The essential constituents of dolerites are a plagioclastic felspar (which may be oligoclase, andesine, bytownite, but generally labradorite or anorthite) with augite (basaltic augite, sometimes approximating to diallage, less frequently malacolite).

NORMAL DOLERITE = plagioclase + augite.

HORNBLENDE-DOLERITE OR PROTEROBASE = plagioclase + augite + hornblende.

OLIVINE-DOLERITE = plagioclase + augite + olivine.

ENSTATITE-DOLERITE = plagioclase + augite + enstatite.

MICA-DOLERITE = plagioclase + augite + biotite.

LEUCOPHYRE is a name given by Gümbel to a rock composed of plagioclase, generally passing into saussurite, a little augite, ilmenite, and some quartz.

Acc. Con. of dolerites are apatite, ilmenite, magnetite, all so common that they may almost be regarded as essential; glaucophane, sphene, zircon, pyrites.

Sec. Con. Chlorite, serpentine, epidote, calcite, leucoxene, actinolite, uralite, quartz, chalcedony, opal, limonite.

17. BASIC NEPHELINE SERIES. DYKE ROCKS OF THE NON-FELSPATHIC DIVISION.

FOURCHITE, from Arkansas, consists of augite, hornblende, and biotite in a vitreous or microfelsitic base.

MONCHIQUITE, occurring in the Lake Champlain Valley, Vermont, U.S., is similar in composition to fourchite, but contains olivine. The chemical composition of the base in these rocks renders it probable that, under suitable conditions, nepheline and plagioclase would have crystallised out. These dykes are associated with nepheline-bearing rocks. The same may be said of ALNÖITE, which consists of biotite in large plates, olivine, augite and magnetite in a groundmass composed of melilite and biotite, with a small quantity of augite and magnetite. *Acc. Con.* Apatite, perowskite. *Sec. Con.* Garnet after melilite and calcite. Occurs as dykes in elæolite syenite, Sweden.

Fourchite, monchiquite, and alnöite may be regarded as lamprophyres of the basic series.

18. GABBRO GROUP. Holocrystalline-granular basic rocks, often coarse in texture, consisting essentially of a plagioclastic felspar (commonly anorthite, sometimes labradorite or bytownite) and a ferro-magnesian silicate which, in NORMAL-GABBRO, is augite; in HORNBLENDE-GABBRO, augite and hornblende; in OLIVINE-GABBRO, augite, hornblende, and olivine.

TESCHENITE consists of plagioclase, augite, hornblende and biotite.

EUCRITE consists essentially of anorthite and augite.

TROCTOLITE (Forellenstein) contains plagioclase and olivine.

NORITE consists of plagioclase and enstatite, or plagioclase and hypersthene. When olivine is present, these rocks are termed OLIVINE-NORITES.

QUARTZ NORITE occurs in the Baltimore gabbro area in Maryland, U.S., and consists chiefly of bytownite, quartz, hypersthene, and secondary hornblende.

Acc. Con. Apatite, zircon, picotite, chromite, garnet, quartz, pyrrhotine, magnetite, titaniferous magnetite, ilmenite, native-iron, biotite, rutile, pyrites, orthoclase.

Sec. Con. Chlorite, epidote, serpentine, saussurite, calcite, garnet, spinel, leucoxene, magnetite.

19. GABBRO GROUP (NEPHELINE SERIES).

THERALITE. A holocrystalline-granular rock, consisting of a lime-soda felspar, nepheline and augite. Biotite is also present, and apatite; occasionally olivine. Magnetite and ilmenite are poorly represented. Theralites occur in Montana, U.S. They bear the same relation to the tephrites that the elæolite-syenites bear to the phonolites.

20. BASIC NEPHELINE SERIES. PLUTONIC ROCKS OF THE NON-FELSPATHIC DIVISION.

IJOLITE (pronounced Iolite, like the *mineral* of that name), from Iwaara in Finland, consists mainly of nepheline, with a little hornblende or mica. It is a holocrystalline rock with a granitoid structure. A nepheline syenite from Dungannon, Ontario, described by Dr. F. D. Adams, approximates in places to ijolite.

21. PERIDOTITE GROUP. Holocrystalline, hypidiomorphic-granular, ultra-basic rocks. Either olivine, or secondary products after olivine, constantly present. Felspar absent, except, occasionally, a very small amount in the picrites. In addition to olivine, minerals of the amphibole, pyroxene, garnet and spinel groups may occur in these rocks.

PICRITE. Essential constituents, olivine and augite; a very small amount of plagioclase is sometimes present as an accessory constituent.

HORNBLENDE PICRITE consists of olivine and hornblende; a little plagioclase or its decomposition products may be present, and occasionally a micaceous mineral allied rather to the chlorite than to the mica group.

Acc. Con. Apatite, biotite, magnetite, ilmenite, and, in some cases, diallage and hypersthene.

Sec. Con. Chiefly serpentine, talc, and chlorite.

SCYELITE. An altered hornblende-picrite, occurring in Caithness. It consists of hornblende (actinolite), a peculiar micaceous mineral of secondary origin, serpentinised olivine, and a little magnetite and chromite.

MICA-PERIDOTITE consists essentially of serpentine (after olivine), biotite and perowskite. *Acc. Con.* Apatite and magnetite. *Sec. Con.* Chlorite, calcite, etc. The biotite is an original constituent, and in this and in the absence of hornblende the rock differs from scyelite.

WEHRLITE. *Ess. Con.* Olivine and diallage; often, however, only represented by the decomposition products, serpentine and chlorite.

EULYSITE may be regarded as a garnetiferous wehrlite. Often serpentinous and the garnets altered to kelyphite.

LHERZOLITE. *Ess. Con.* Olivine, diallage, and a rhombic pyroxene (generally enstatite or bronzite). One or more minerals of the spinel group are usually present (picotite, chromite, pleonaste), together with some magnetite and ilmenite.

SAXONITE or HARZBURGITE. *Ess. Con.* Olivine and a rhombic pyroxene (bronzite, often altered to bastite).

Acc. Con. Magnetite, ilmenite, hornblende, biotite, chromite, picotite, and occasionally a very little plagioclase.

CORTLANDITE. *Ess. Con.* Olivine, hornblende, and hypersthene.

DUNITE consists essentially of olivine and chromite. Picotite, pyrope, magnetite, ilmenite, apatite, and, in some cases, a very little enstatite are present. Through decomposition the rocks of the peridotite group pass into serpentines.

22. PYROXENITE GROUP. This group includes certain holocrystalline-granular plutonic rocks, which consist of one or more species, or varieties, of pyroxene or amphibole.

HORNBLENDITE = hornblende + augite.

ECLOGITE = smaragdite + omphacite + garnet.

BRONZITITE = bronzite. HYPERSTHENITE = hypersthene.

WEBSTERITE = enstatite + diallage. DIALLAGITE = diallage.

ALTERED ERUPTIVE ROCKS.

The most important altered eruptive rocks constitute several groups, the names of which are given on the tables in italics.

23. *Felsite Group.* There are felsites which are essentially apophyses of plutonic rocks, such as granites and syenites, those of granitic origin being more or less closely allied to the haplites and microgranites, while those originating from syenitic masses would be naturally poorer in silica. Such rocks do not belong to the group under consideration, which includes only those felsites which have resulted from the devitrification of lavas of the rhyolite and occasionally of the trachyte groups. The felsites of the former differ from those of the latter group in the proportion of silica present and in the nature of the felspathic constituent. The general characters of such felsites have already been given under the "Rhyolite Group," p. 15.

24. *Arkose.* This is a more or less coherent rock, consisting of the *débris* of granite, and either without a cementing material, or cemented by kaolin, etc.

China-stone results from the decomposition of granite, and consists of kaolin and quartz. *Kaolin* results from the decomposition of the felspars.

25. *Porphyrite Group.* Porphyrites are altered andesites, the felspars having been more or less converted into kaolin, the hornblende and augite into chlorite, serpentine, etc., the hypersthene into bastite, and the magnetite into hematite or limonite. Biotite also is often represented only by pseudomorphs of limonite. Each member of the andesite group may have its representative among the porphyrites; thus the hornblende andesites pass into hornblende porphyrites, the mica andesites into mica porphyrites, and so on. The porphyrites resulting from the alteration of rocks of the dacite series contain more or less quartz. The glassy matter present in the andesites is converted in the corresponding porphyrites into devitrification products.

26. *Propylite Group.* The rocks termed propylites represent an altered condition of hornblende- and augite-andesites and dacites. The alteration appears to have been effected by solfataric agency and by the action of H_2S, and consists in the decomposition of the felspars, amphibole, pyroxene, mica, etc., and the development of calcite, chlorite, epidote, actinolite, and pyrites. The glassy matter in the original rocks has also been completely altered. Valuable ore deposits are not unfrequently associated with propylites.

27. *Melaphyre Group.* The melaphyres are altered basalts, and bear the same relation to those rocks that porphyrites do to andesites. There may, therefore, be as many varieties of melaphyre as of basalt. The secondary minerals present in melaphyres are chlorite, epidote, serpentine, dolomite, calcite, magnetite, and limonite. The cavities in the amygdaloidal melaphyres are often filled with chlorite, delessite, calcite, and chalcedony, or with zeolites (scolecite, thomsonite, natrolite, mesolite, stilbite, heulandite, phillipsite, gismondine, chabazite, etc.).

28. *Diabase Group.* The rocks of this group are more or less altered dolerites, and, like the melaphyres, are rich in secondary minerals. Among these, chlorite is one of the most prevalent. Epidote, serpentine, leucoxene, magnetite, and calcite are also of frequent occurrence, as well as zeolites (analcime, natrolite, etc.). Diabase constitutes much of the "greenstone" of the older authors.

29. The *Ophites* of the Pyrenees are closely related to diabase. They contain

no olivine and are essentially plagioclase-augite rocks, in which the augite is mostly converted into uralite. Ilmenite, generally altered to leucoxene, apatite, epidote, chlorite, etc., are frequently present. In these rocks the so-called ophitic structure is typically developed.

30. *Epidiorites* are altered dolerites in which the augite is represented by secondary hornblende (actinolite, smaragdite, uralite). The felspars are generally much altered. Chlorite, ilmenite, and magnetite are commonly present.

31. *Euphotides* are altered gabbros, in which the felspar has been converted into saussurite and the augite into hornblende.

32. *Serpentines.* Although serpentine occurs in not inconsiderable quantity in the basic rocks, owing to the alteration of olivine, pyroxene, and amphibole, yet the ultra-basic rocks, which are composed almost exclusively of such minerals, yield, upon decomposition, rocks consisting wholly of serpentine. These true serpentines are often veined by the fibrous variety, chrysotile, and by steatite. They sometimes retain vestiges of olivine, diallage, etc., in an unaltered condition. The structure of the original minerals, irregular cracks, as in olivine, or regular cleavage-planes, as in augite and hornblende, may frequently be detected under the microscope. Thus, serpentine after olivine shows an irregular mesh-structure; after hornblende a lattice-structure, and after augite a rectangular grid-structure, the bars of the lattice- and grid-structures respectively intersecting in angles which correspond, in the first case with those formed by the prismatic cleavages of hornblende, in the second with those formed by the corresponding cleavages in augite. Any considerable admixture of calcite with serpentine constitutes the rock known as *ophicalcite.*

33. *Peridotite Dykes.* Dyke representatives of the peridotite group have been described by Diller as traversing slates and sandstones of carboniferous age in the East of Kentucky. They have the general character of Dunite and consist of olivine and pyrope in a more or less altered condition with enstatite, ilmenite, magnetite, and about 14 per cent. of dolomite. The olivine is partly altered to serpentine, and the pyrope to biotite and picotite.

34. *Kimberlite* and *picrite-porphyrite* may be regarded as volcanic representatives of the peridotites, the former occurring at the Kimberley diamond mines, South Africa, and consisting of olivine, bronzite, and biotite, more or less altered, together with some ilmenite, pyrope, etc., in a serpentinous groundmass. This rock in a still more decomposed condition and containing fragments of carbonaceous slate constitutes the "blue-ground" of the miners, in which the diamonds are found.

Picrite-porphyrites consist of olivine, augite, ilmenite, magnetite, apatite, etc., with a not inconsiderable amount of vitreous matter. Those hitherto described appear to be mostly of Jurassic and Cretaceous age.

35. *Tuffs* are essentially pyroclastic rocks, or such as consist of fragments of lavas (scoria, pumice, lapilli), of lavas reduced to mere dust, or of rock matter originally ejected in a molten condition, and ranging from masses a foot or more in diameter (bombs) to microscopic drops of vitreous matter. Among such heterogeneous material small crystals, entire or broken, and occasionally fragments of plutonic or sedimentary rocks may occur, the latter having been brought up the volcanic pipe from considerable depths. These ejectamenta may eventually become cemented and strongly coherent. From their mode of origin, tuffs naturally vary greatly in their composition, and, when it can be ascertained, it is customary to prefix the name of the lava from which the constituents have been mainly derived, as *melaphyre-tuff*, *andesite-tuff*, etc. Strictly speaking, the term *tuff* is restricted to the finer grained or pulverulent volcanic ejectamenta; but, in a broader sense, it may include not only accumulations of scoria and lapilli, but also the materials resulting from the decomposition and atmospheric degradation of lavas.

EXPLANATORY NOTES ON THE DETERMINATIVE TABLES.

1. In the column headed *Cryst. Syst.* the following abbreviations are used:— Am. = amorphous. Gran^r. = granular. Fib^s. = fibrous. Cub^c. = cubic. Hex. = hexagonal. $\frac{\text{Hex.}}{2}$ = rhombohedral. $\frac{\text{Hex.}}{4}$ = tetartohedral. Tet. = tetragonal. Rh^c. = rhombic. Mon. = monoclinic. Tri. = triclinic. A symbol such as $\genfrac{}{}{0pt}{}{\text{Mon.}}{\text{p. hex.}}$ indicates that the mineral is really monoclinic in crystallisation, although apparently hexagonal.

2. In the column headed *Cleavage*, only the most easy cleavages are, as a rule, given. The symbols of the forms to which the cleavages are parallel are in the Weiss-Miller notation. The corresponding symbols in Naumann's notation are:—

Cubic System: $O=(111)$. $\infty O\infty=(100)$. $\infty O=(110)$.

Hexagonal System: $P=(10\bar{1}1)$. $\infty P=(10\bar{1}0)$. $\infty P2=(11\bar{2}0)$. $OP=(0001)$.

(Rhombohedral): $R=\kappa(10\bar{1}1)$. $\infty R=\kappa(10\bar{1}0)$. $-\frac{1}{2}R=\kappa(00\bar{1}2)$. $OR=\kappa(0001)$.

Tetragonal System: $P=(111)$. $\infty P=(110)$. $\infty P\infty=(100)$. $OP=(001)$.

Rhombic System: $P=(111)$. $\infty P=(110)$. $\infty P\bar{\infty}=(100)$. $\infty P\breve{\infty}=(010)$. $OP=(001)$.

Monoclinic System: $\infty P=(110)$. $\infty P\overset{+}{\bar{\infty}}=(100)$. $\infty P\grave{\infty}=(010)$. $OP=(001)$.

Triclinic System: $\infty P_{,}'=(1\bar{1}0)$. $\infty'_{,}P=(110)$. $\infty P\bar{\infty}=(100)$. $\infty P\breve{\infty}=(010)$. $OP=(001)$.

3. In the column headed *Opt. Sign*, the positive + or negative — character of the double refraction of the mineral is shown. In + uniaxial crystals, *i.e.*, those crystallising in the hexagonal and tetragonal systems, $\mathfrak{c}=c$, while in — uniaxial crystals $\mathfrak{a}=c$. (Determined by mica-plate or selenite-plate.)

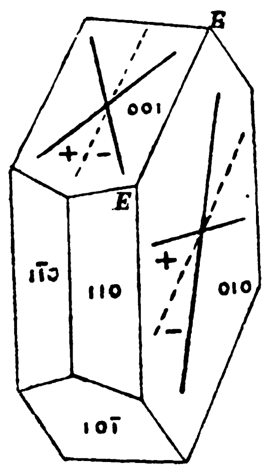
In optically biaxial crystals, those in which $\mathfrak{c}$ is the acute bisectrix (determined by quartz-wedge, Klein's plate, selenite-plate or mica-plate) are +, while those in which $\mathfrak{a}$ is the acute bisectrix are —.

4. In the column headed *Extinctions*, the extinction in uniaxial crystals is parallel and at right angles to the principal crystallographic axis, while sections at right angles to that axis remain dark during a complete revolution between crossed nicols. The only exception to this rule is to be seen in thick basal sections of crystals possessing circular polarisation (*e.g.* quartz and cinnabar), but in thin sections circular polarisation gives no appreciable sign of its existence.

In the rhombic system the directions of maximum extinction are parallel to crystallographic axes (straight extinction). In the monoclinic system the extinction angle is measured from the vertical crystallographic axis *c*, or from an edge parallel to that axis.

In the triclinic system it may be measured from an edge. In the plagioclastic felspars the edge chosen is that formed by the basal and brachypinacoids, $001/010=OP/\infty P\breve{\infty}$. These measurements are best made upon cleavage-plates

taken respectively parallel to (001) and to (010). Such extinctions are termed positive or negative according to the direction in which the crystal has to be turned in order to attain its maximum extinction. These directions are indicated in the annexed figure, where E E represents the edge $^{001}/_{010}$. The expressions positive and negative, as here applied, bear no relation to the + or − sign of double refraction. (Determined between crossed nicols only, or in conjunction with Bertrand's stauroscope eye-piece or Calderon's, or Brezina's plate.)



5. In the column headed *Relief*, the following scale, that of MM. Michel Lévy and Lacroix, is employed.

$$\text{Mean Refraction } N=\frac{\alpha+\beta+\gamma}{3} \text{ or } \frac{n^{\epsilon}+2\,n^{\omega}}{3}.$$

1.	$N<1{\cdot}55$	Little or no relief very weak.	1.
2.	„ $=1{\cdot}55$ to $1{\cdot}60$	weak.	2.
3.	„ $=1{\cdot}61$ „ $1{\cdot}65$	medium.	3.
4.	„ $=1{\cdot}66$ „ $1{\cdot}70$	marked.	4.
5.	„ $=1{\cdot}71$ „ $1{\cdot}75$	strong.	5.
6.	„ $=1{\cdot}76$ „ $2{\cdot}$	very strong.	6.
7.	„ $>2.$	extremely strong.	7.

The relief in which a mineral appears is proportional to the difference between the mean refraction of the mineral and that of the medium which surrounds it. Thus albite with $N=1{\cdot}535$ is barely visible when mounted in Canada balsam in which $N=1{\cdot}530$, while rutile, with $N=2{\cdot}712$, mounted in that medium, appears strongly outlined and with a very broad black border due to total reflection. In some cases, owing to the same cause, the surface of the section looks rough or shagreened.

6. In the column headed *Interf. Col.*, the colours seen in polarised light, in sections of average thickness, *i.e.*, from about 0·04 to 0·06 of a millimetre, are given. The interference colour is due to the unequal retardation of the two polarised beams of light in their passage through a doubly refracting crystal. The colour is influenced (1) by the thickness of the section, (2) by the direction in which the crystal is cut, (3) by the colour of the light in which it is examined.

The strength of the double refraction, $\gamma-\alpha$ or $n^{g}-n^{p}$, attains its maximum, in uniaxial crystals, in sections parallel to the optic axis and in biaxial crystals in sections parallel to the optic axial plane. To compare, therefore, the relative strength of double refraction in any two minerals it is necessary that the sections should be cut in that direction in which they exhibit the strongest colours in polarised light.

The expression *very low* indicates that part of Newton's colour-scale represented by the greys and pale-yellow of the first order, as seen at the thin end of a quartz-wedge. *Low* is employed for colours which do not range much above the first order. *High* denotes colours of the second, and lower colours of the third order. *Very high* implies colours of the third order, and *extremely high* those of the fourth order.

7. In the column marked 2 *E*, the apparent angle of the optic axes is given.

This may be roughly estimated by means of an eye-piece micrometer, in which the value of the divisions in degrees has been previously ascertained by measuring the separation of the vertices of the dark brushes of the interference-figure, when seen in the diagonal position, in a biaxial mineral, of which the optic axial angle has already been determined on an axis-angle goniometer, or by means of a stage-goniometer attached to the microscope.

8. In the column headed *Colour in thin section*, the colours mentioned are those seen in ordinary transmitted light. In some minerals, such as cossyrite and chromite, it is necessary that the section should be excessively thin in order to transmit light.

9. In the column headed *Sign in the direction of elongation*, the positive or negative character of the double refraction, with reference to the zone of elongation or of flattening of the crystal, is given. In order that the signs in this column may not be mistaken for those given in the column relating to the double refraction of the mineral, they are not so heavily printed.

10. The final column includes notes on pleochroism, character of dispersion[1] in interference-figures, position of optic axial plane and other matters which could not conveniently be tabulated on so small a page.

The absorption schemes indicate the relative absorption of light for vibrations respectively parallel to $\mathfrak{a}$, $\mathfrak{b}$, and $\mathfrak{c}$. Thus :—$\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$ indicates that the absorption of light for vibrations $\parallel \mathfrak{a}$ is greater than that for those $\parallel \mathfrak{b}$, while the absorption for vibrations $\parallel \mathfrak{b}$ is greater than that for those $\parallel \mathfrak{c}$. Also $\mathfrak{c} \geqq \mathfrak{b} > \mathfrak{a}$ denotes that the absorption for vibrations $\parallel \mathfrak{c}$ may, in some cases, be greater than, in others equal to those $\parallel \mathfrak{b}$, while the absorption for vibrations $\parallel \mathfrak{b}$ is greater than that for vibrations $\parallel \mathfrak{a}$.

$\mathfrak{a}$, $\mathfrak{b}$, and $\mathfrak{c}$ respectively denote the maximum, mean, and minimum axes of optical elasticity, respectively corresponding with the minimum, mean, and maximum refractive indices, α or n^p, β or n^m, and γ or n^g.

In biaxial crystals $\mathfrak{a}$ and $\mathfrak{c}$ always lie in the optic axial plane and are the bisectrices, while $\mathfrak{b}$ is the optic normal.

a, *b*, and *c* are crystallographic axes. Of these *c* is always the vertical axis. In the rhombic and triclinic systems *a* is the brachy- and *b* the macro-diagonal, while in the monoclinic system *a* is the clino- and *b* the ortho-diagonal.

The pleochroism may be determined by means of the polariser only, the analyser being removed, or by using a double-image prism over the eye-piece, both polariser and analyser being removed and a diaphragm inserted in the focus of the eye-piece.

The latter method is equivalent to an adaptation of Haidinger's dichroscope to the microscope. Haidinger's instrument can only be employed upon thin sections when the crystal to be examined occupies a comparatively large area.

[1] To ascertain the character of dispersion with the Dick Microscope the lower tube lens should be used. The employment of an immersion objective of large angular aperture is also advantageous.

DETERMINATIVE TABLES.

Abbreviations at Heads of Columns.

Cryst. Syst. = *Crystallographic System*. Opt. Sign = *Optical Sign*.

Interf. Col. = *Interference-colour*. 2E = *Apparent angle of the optic axes*.

FELSPAR

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E
ORTHOCLASE . (Sanidine)	Mon.	(001) (010) 90°	−	on (001)=0° on (010)=+5°	very weak 1	low in 1st ord.	125°
MICROCLINE .	Tri. p. mon.	" " 90° 16′	−	on (001)=+15° on (010)=+5°	"	"	130°
ANORTHOCLASE	Tri. p. mon.	" " 90° 20′	−	on (001)=+1° to 6° on (010)=+6°	"	"	72°–88°
ALBITE . . . Ab	Tri.	" " 93° 36′	+	on (001)=+5° on (010)=+20°	"	1st ord.	very large
OLIGOCLASE . Ab_4An_1	Tri.	" " 93° 50′	−	on (001)=+2° to 5° on (010)=+4° to 7°	"	"	"
Ab_3An_1				on (001)= 0° on (010)= 0°			
ANDESINE . . Ab_3An_2	Tri.	"	−	on (001)=−8° 6′ on (001)=−1° to 3° 6	weak 2	"	"
LABRADORITE Ab_1An_1	Tri.	" " 93° 20′	+	on (001)=−5° on (010)=−16°	"	"	"
Ab_3An_4				on (001)=−7° on (010)=−21°			
BYTOWNITE . Ab_1An_3	Tri.	"		on (001)=−17° 40′ on (010)=−29° 28′	"	"	
ANORTHITE . An	Tri.	" " 94° 10′	−	on (001)=−33° on (010)=−37°	"	"	"

NOTE. In the orthoclastic felspars the optic axial plane lies as a rule at right angles to the plane of symmetry, making an angle of from 3° to 7°, with the plane of the crystallographic axes *a*, *b*, in the obtuse angle *β*. In soda-orthoclase this inclination may amount to 10° or 12°. In certain cases (abnormal orthoclase) the optic axial plane lies in the plane of symmetry, *i.e.* ‖ (010).

GROUP.

TABLE I.

Colour in thin section.	Sign in the direction of elongation.	Notes.	
When free from inclusions and decomposition products, colourless.	—	Twinning on Carlsbad type common, on Baveno and Manebach types less so. Dispersion horizontal $\rho > v$, inclined $\rho < v$. In Carlsbad type elongation $\parallel c$, in Baveno type $\parallel a$. Crystals of Sanidine have a tabular habit $\parallel$ (010).	
Ditto	—	Polysynthetic twinning on Albite and Pericline types. Dispersion $\rho > v$.	
Ditto	—	Dispersion $\rho > v$.	
Ditto	—	Twinning on (010) polysynthetic (Albite type), also twin axis the macro-diagonal b, and plane of composition the "rhombic section" (Pericline type). Dispersion horizontal $\rho < v$.	
			General Note.
Ditto	—	Dispersion crossed $\rho > v$.	Twinning on the Carlsbad type (plane of composition 010), on the Baveno type (plane of composition 021), and on the Manebach type (plane of composition 001), may also occur in the plagioclastic felspars.
Ditto	—	Dispersion inclined $\rho > v$.	Repeated twin lamellation, although not restricted to these minerals, is very characteristic of the plagioclastic felspars. Being colourless in thin section none of the felspars exhibit pleochroism.
Ditto	—	Dispersion crossed $\rho > v$.	Anorthite and Labradorite are soluble in hydrochloric acid. When doubt exists concerning the species of a felspar, Szabo's flame-test may be advantageously employed. (See Cole's "Aids in Practical Geology," pp. 74–81. Also "Rock-forming Minerals," Rutley, pp. 8–12.
Ditto			
Ditto	±	Dispersion inclined $\rho < v$. Broad twin lamellæ and wide extinction angles are very characteristic of anorthite.	

NOTE. In microcline the optic axial plane is approximately perpendicular to the macrodiagonal axis b (82°–83°). In the plagioclastic felspars the position of the optic axial plane varies progressively from albite at one end to anorthite at the other end of the series.

The extinction angles of the plagioclastic felspars, given in the above table, are the observed angles of Max Schuster, which differ but little from the calculated angles of M. Michel-Lévy.

AMPHIBOLE

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E
ANTHOPHYLTITE	Rh^c.	(110) 124°	+	straight	medium 3	high, 2nd ord.	177°
GEDRITE . . .	Rh^c.	(110)	−	„	„	„	88°
ACTINOLITE . .	Mon.	(110) 124° 30′	−	15° with *c*	„	high, 2nd & 3rd ord.	77°
HORNBLENDE . (common var.)	Mon.	„	−	15°–22° with *c*	„	„	> 180°
HORNBLENDE . (basaltic var.)	Mon.	„	−	0°–10° with *c*	„	„	
ARFVEDSONITE .	Mon.	(110) 123° 55′	+	14° with *c*	marked 4	higher than hornblende	
GLAUCOPHANE .	Mon.	(110) 124° 30′	−	4°–6° with *c*	medium 3	lower than arfvedsonite	
CROSSITE . . .	Mon.	(110) 126°	?	13° with *c*			
RIEBECKITE . .	Mon.	(110)	+	5°–7° with *c*	marked 4	low	large
COSSYRITE . .	Tri.	(110) (1̄10) 114° 9′	?	39° with *c*, on (010)			?

PYROXENE

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E
ENSTATITE . .	Rh^c.	(110) (010)	−	straight	marked 4	< yellow 1st ord.	
BRONZITE . . .	Rh^c.	„ „	±	„	„	„	
HYPERSTHENE .	Rh^c.	(110) 92° „	−	„	„	up to red 1st ord.	
DIALLAGE . .	Mon.	(100) (110)	+	39° with *c*	„	high, 2nd & 3rd ord.	
MALACOLITE .	Mon.	(110) 87°	+	38° with *c*	„	little higher than diallage	112°
AUGITE . .	Mon.	„	+	up to 45° with *c*	strong 5	higher than malacolite	
AEGERINE . .	Mon.	(110) (010) 87°11′	−	3°–5° with *c*	„	higher than augite	

NOTE.—In all rhombic amphiboles and pyroxenes the optic axial plane lies || (010), except in the altered pyroxene, bastite, in which it lies || (100).

GROUP.

Colour in thin section.	Sign in the direction of elongation.	Notes.
colourless, yellowish, yellowish-green	+	Pleochroism not perceptible in thin sections. Dispersion $\rho < \upsilon$. Crystals traversed by cracks $\parallel$ (001).
ditto	+	Pleochroism not perceptible in thin sections. Dispersion $\rho > \upsilon$.
grass-green, greyish-green, weak-green	+	Pleochroism weak, in green tints, $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. Dispersion $\rho < \upsilon$. (TREMOLITE. Colourless, not pleochroic, otherwise like actinolite.)
green, brown	+	Pleochroism strong, $\mathfrak{c}$ and $\mathfrak{b}$ green, $\mathfrak{a}$ yellowish, generally $\mathfrak{c} \geqq \mathfrak{b} > \mathfrak{a}$. Dispersion $\rho < \upsilon$.
brown	+	Pleochroism strong, in brown and yellow tints, $\mathfrak{c} \geqq \mathfrak{b} > \mathfrak{a}$. The common var. shows like opt. characters after heating.
olive-green, deep greenish-blue	+	Pleochroism strong, $\mathfrak{a}$ greenish-blue, $\mathfrak{b}$ blue, $\mathfrak{c}$ greenish-grey. $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$.
blue	+	Pleochroism very strong, $\mathfrak{c}$ blue, $\mathfrak{b}$ violet, $\mathfrak{a}$ pale-yellow. Crystals traversed by cracks.
blue, yellowish-blue		Pleochroism very strong, $\mathfrak{a}$ sky-blue to dark-blue, $\mathfrak{b}$ reddish to purplish-violet, $\mathfrak{c}$ yellowish-brown to greenish-yellow, $\mathfrak{a} \underset{>}{=} \mathfrak{b} > \mathfrak{c}$.
deep-blue or green	−	Pleochroism very strong, $\mathfrak{c}$ green, $\mathfrak{b}$ blue, $\mathfrak{a}$ deep-blue. $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$.
deep-brown. Only translucent in very thin sections	?	Occurs in pantellerites.

GROUP.

almost colourless, yellowish	+	Pleochroism feeble, generally inappreciable. Dispersion $\rho < \upsilon$.
ditto	+	Pleochroism feeble, $\mathfrak{a}$ yellowish, $\mathfrak{b}$ yellowish, $\mathfrak{c}$ greenish. Cleavage-flakes $\parallel$ (010) give no interference-figure, but, in the altered form (bastite), a negative bisectrix is seen.
greenish, reddish, greenish-brown	+	Pleochroism, $\mathfrak{a}$ reddish-brown, $\mathfrak{b}$ reddish-yellow, $\mathfrak{c}$ green. Absorption weak. Dispersion $\rho > \upsilon$.
greenish, yellowish	+	Pleochroism variable, weak. Cleavage-flakes $\parallel$ (110) show one of the ring-systems in convergent polarised light. Dispersion inclined.
colourless, greenish	±	Ditto ditto
green, brown, violet	+	Ditto ditto
green (acmite, brown) not very translucent	−	Pleochroism, $\mathfrak{a}$ green, $\mathfrak{b}$ olive- to sap-green, $\mathfrak{c}$ grass-green (aegirine); $\mathfrak{a}$ brown, $\mathfrak{b}$ clear-brown, $\mathfrak{c}$ greenish-yellow (acmite).

NOTE.—In all monoclinic amphiboles and pyroxenes the optic axial plane lies in the plane of symmetry, *i.e.* $\parallel$ (010).

M I C A

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E.
Muscovite . .	Mon. p. hex.	(001)	−	parallel to the traces of the basal cleavage	weak 2	very high up to 3rd & 4th ord.	40°–70°
Paragonite .	Mon.	„	−	ditto		ditto	70°
Lepidolite . .	Mon.	„	−	ditto		ditto	50°–70°
Biotite . . .	Mon.	„	−	ditto	medium 3	ditto	0°–73°
Lepidomelane .	Mon.	„	−	ditto		ditto	„ „
				F E L S P A T H O I D			
Nepheline . . (Elæolite)	Hex.	(0001) (10$\bar{1}$0) when altered	−	$\parallel$ and $\perp c$. Basal sections dark in all azimuths	very weak 1	very low, not above yellow 1st ord.	
Leucite . . .	Cub^{c}. p. rh^{c}.			Isotropic Anomalous double refraction	ditto	very low, grey of 1st ord.	
Sodalite . . .	Cub^{c}.	(110) difficult		Isotropic	ditto		
Haüyne . . .	Cub^{c}.	ditto		„	ditto		
Nosean . . .	Cub^{c}.	ditto		„	ditto		
Tourmaline .	$\frac{\text{Hex.}}{2}$	no cleavage seen in thin sections	−	$\parallel$ and $\perp c$. Basal sections dark in all azimuths	medium 3	high, 2nd ord.	
Idocrase . .	Tet.	(110) (001) very difficult	−	ditto	strong 5	very low, grey of 1st ord.	
Topaz . . .	Rh^{c}.	(001)	+	straight	medium 3	low up to red of 1st ord.	70°–120°

G R O U P . TABLE III.

Colour in thin section.	Sign in the direction of elongation.	Notes.
colourless, yellowish, greenish	+	Twinning plane usually ⊥ (001) and lying in the zone 001 : 110, the plane of composition being (001).
ditto	+	In muscovite, paragonite, and in most lepidolites (also in anomite, a mica allied to biotite), the optic axial plane lies at right angles to the plane of symmetry, also at right angles to the guide-line of the percussion-figure.
ditto	+	
brown, green	+	In biotite, phlogopite, lepidomelane, and zinnwaldite, the optic axial plane lies in the plane of symmetry, also parallel to the guide-line of the percussion-figure.
deep-brown	+	

G R O U P .

colourless		Often altered to natrolite and analcime. Soluble in hot H Cl, with separation of gelatinous silica. In elæolite, inclusions of amphibole, hematite, etc., common. Cancrinite is allied to nepheline, but is a distinct species, containing $Na\,Co_3$ and H_2O. It occurs in ditroite.
ditto		Lamellar twinning common in leucite, except in very small crystals. The latter are isotropic. The larger crystals show weak double refraction, but become isotropic at a temperature of 500° C.
colourless, blue, green, yellow		Readily soluble in H Cl, with separation of gelatinous silica, which on evaporation yields crystals of common salt.
ditto		Readily soluble in H Cl, with separation of gelatinous silica, which on drying yields crystals of gypsum, if the acid used be sufficiently dilute.
ditto		Ditto for nosean, except that, on drying, few or no crystals of gypsum are formed.
brown, blue, violet, green, etc. Rarely colourless	−	Pleochroism strong. O > E. Crystals often hemimorphic. Zonal structure at times. Radial aggregates common.
colourless, brownish		Optical anomalies common, but not appreciable in thin sections. Double refraction occasionally +. Idocrase occurs mostly in altered limestones.
colourless		Pleochroism not perceptible in thin sections.

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E.
Scapolite . .	Tet.	(110) sometimes (100)	−	‖ and ⊥ *c*. Basal sections dark in all azimuths	weak 2	higher than quartz, but very variable	
Meionite . .	Tet.	ditto	−	ditto	ditto		
Melilite . .	Tet.	(001)	− +	ditto	medium 3	very low, grey 1st ord.	
Andalusite .	Rh^c.	(100)	−	straight	medium 3	up to blue 2nd ord.	>180°
Sillimanite .	Rh^c.	„	+	„	marked 4	high, up to greenish-blue 3rd ord.	40°
Olivine . . .	Rh^c.	(100) (010)	+	straight	marked 4	very high, up to 4th ord.	>180°
Fayalite . .	Rh^c.	„ „	−	„	ditto	higher than olivine	
Dichroite . .	Rh^c.	(010) (001)		straight	very weak 1	not above red of 1st ord.	64°–150°
Garnet . . .	Cub^c.			Isotropic. Anomalous double refraction at times	very strong 6		
Spinel . . .	Cub^c.			Isotropic	strong 5		
Pleonaste . .	Cub^c.			„	ditto		
Picotite . .	Cub^c.			„	ditto		
Chromite . .	Cub^c.			„	ditto		

Colour in thin section.	Sign in the direction of elongation.	Notes.
colourless		Basal sections generally give a good uniaxial interference-figure in convergent light. This at once distinguishes scapolite from felspars or dichroite, while its negative double refraction distinguishes it from quartz, and its higher interference-colours from apatite.
colourless or yellowish	+	Plug structure common. Gelatinises with H Cl.
colourless	—	Pleochroism sometimes strong, frequently absent. Optic axial plane ‖ (010).
„	+	Optic axial plane ‖ (100). Dispersion $\rho > \upsilon$. Occurs chiefly in crystalline schists.
colourless, greenish, yellowish, less often red to reddish brown	±	Crystals often much rounded or corroded and traversed by irregular cracks. The cleavages are only seen in sections of decomposed crystals. Gelatinises with H Cl. Dispersion $\rho < \upsilon$. Optic axial plane ‖ (001). Surfaces of sections appear rough or shagreened. Frequently altered to serpentine.
colourless, reddish, yellowish		Fayalite gelatinises with H Cl. Dispersion $\rho < \upsilon$. Occasionally met with in the lithophyses of rhyolites.
colourless	—	Insoluble in H Cl. Often altered to pinite (=muscovite+chlorite, etc.). Dispersion $\rho < \upsilon$. Pleochroism $\mathfrak{a}$ blue-grey, $\mathfrak{b}$ dark blue, $\mathfrak{c}$ yellow. The pleochroism is barely perceptible in some thin sections. Optic axial plane ‖ (100).
colourless, green (grossular) red (almandine) brown (melanite) reddish (common garnet)		Garnets occur in rhombic dodecahedra or in rounded and sometimes very irregularly-shaped grains. Zonal structure common. Slowly acted on by acids. Difficultly fusible with $Na_2 Co_3$.
colourless, rose-red		Not acted upon either by acids or by heating with Na_2Co_3.
green		Ditto
brown		Ditto
brown		Only translucent in extremely thin sections.

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E.
RUTILE . .	Tet.	(110) 90°	+	‖ and ⊥ c. Basal sections dark in all azimuths	extremely strong 7	extremely high 4th ord.	
TINSTONE .	Tet.	(100) 90°	+	ditto	ditto	ditto	
ZIRCON . .	Tet.	(110) 90°	+	ditto	very strong 6	ditto	
QUARTZ . .	Hex. / 4	Inappreciable	+	‖ and ⊥ c. Circular polarisation inappreciable in microscope-sections	weak 2	low, not above red of 1st ord.	
CHALCEDONY	Hex.	„	+	‖ and ⊥ to length of fibres	ditto		
TRIDYMITE .	„	„	+	Feeble double refraction. Scales viewed ⊥ (0001) isotropic	ditto		
OPAL . . .	Am.	none		Anomalous double refraction, due to strain, especially in hyalite	ditto		
CORUNDUM .	Hex. / 2	none	−	‖ and ⊥ c. Basal sections dark in all azimuths	very strong 6	low, not above red of 1st ord.	
EUDIALYTE .	Hex. / 2	(0001)	+	‖ and ⊥ c.	medium 3	very low, grey of 1st ord.	
PEROWSKITE	Cub^c.? p. cub.	(100)	+	Anomalous double refraction	extremely strong 7	very low, not above yellow of 1st ord.	40°–44°
SPHENE . .	Mon.	(110)	+	⊥ $(10\bar{2})$ or 50° 48′ with a in the obtuse angle β.	very strong 6	extremely high 4th ord. nearly as high as rutile	50°
MONAZITE .	Mon.	(001) . (100)	+		very strong 6	high	28°–50°
APATITE .	Hex.	(0001) imperfect	−		medium 3	very low, not above yellow of 1st ord.	

Colour in thin section.	Sign in the direction of elongation.	Notes.
yellow, brownish-red, violet	+	Crystals frequently more or less rounded. Twins common on (101) and on (301), the former geniculate, the latter kite-shaped. Also in small groups of needle-like crystals forming meshes (sagenite) in conformity with twinning.
colourless, yellow, brown	+	Interference figure anomalous at times, the cross breaking up into dark brushes.
colourless, yellowish, reddish	+	Zonal structure common.
colourless	+	Thin basal sections show a dark cross without rings. Inclusions of H_2O and CO_2 often present.
"	—	The apparently optically negative character is due to a being the axis of elongation of the fibres, the elongation being at right angles to that of quartz. The fibres of chalcedony are biaxial.
"	—	Tridymite generally occurs in aggregates of overlapping scales.
"	—	Becomes strongly stained when moistened with solution of fuchsine (roseaniline).
colourless, blue	+	Crystals traversed by basal and rhombohedral solution planes, simulating cleavage. Surfaces of sections appear rough.
colourless, reddish		Occurs chiefly in the elæolite syenites.
greyish-brown, violet, brownish-yellow		Descloizeaux regards the dodecahedron as built up of twelve hemipyramids (monoclinic), the lozenge-shaped base of each corresponding to a face of the rhombic dodecahedron. Optic axial plane parallel to the longer diagonal of each lozenge. Dispersion horizontal.
colourless, yellowish, reddish-brown		In sphene the optic axial plane lies in the plane of symmetry. Pleochroism weak, in very thin sections barely perceptible. Dispersion very strong, inclined $\rho > \upsilon$. Twinning on (001).
brownish, yellowish		Horizontal dispersion $\rho < \upsilon$. Twinning on (100). In the spectroscope gives absorption bands between the green and orange, due to didymium.
colourless, bluish	—	Crystals frequently show gas- and fluid-inclusions. Optical anomalies common.

E P I D O T E

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E.
ZOISITE . . .	Rh^c.	(010)	+	straight	marked 4	very low, barely to yellow of 1st ord.	10°–100°
THULITE . . .	Rh^c.	(001)	+	"	ditto		0°–40°
EPIDOTE . . . (Pistacite)	Mon.	(001)	−	2°–3° with c	strong 5	very high, 3rd and 4th ord.	> 180°
PIEDMONTITE . (Withamite)	Mon.	"	+	4°–5° with c	very strong 6	ditto	> 180°
ORTHITE . . . (Allanite)	Mon.	"	−	30° with c	ditto	very high, but not so high as epidote	"

C H L O R I T E

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E.
RIPIDOLITE . .	Mon. p. hex.	(001)	±	⊥ (001) gives no complete extinction	weak 2	very low, grey 1st ord.	v. small to 0°
PENNINE . . .	Mon.	"	±	ditto	ditto	ditto	ditto
CLINOCHLORE .	Mon.	"	+	12°–15° with a normal to (001)	ditto	low, up to blue of 2nd ord.	0°–75°
DELESSITE . .	?	"	−	⊥ (001)	medium 3		0°
TALC	Mon.?	(001)	−	respectively ∥ b and c	weak 2	very high, 4th ord.	10°–20°
KAOLIN . . .	Mon. p. hex.	"	−	20° with a normal to (001)	very weak		large

GROUP. TABLE VI.

Colour in thin section.	Sign in the direction of elongation.	Notes.
colourless, green, greenish-grey	±	Crystals very seldom show terminal faces. No perceptible pleochroism.
rose-red		Pleochroism very strong. 𝔞 reddish-white, 𝔟 rose-red, 𝔠 yellowish. Dispersion $\rho < \upsilon$.
colourless, yellowish-green	±	Crystals often twinned on (100). Optic axial plane ‖ (010). Pleochroism varies in strength: generally 𝔞 colourless, 𝔟 yellowish-green, 𝔠 siskin-green. Crystals elongated on the orthodiagonal *b*. Dispersion inclined $\rho > \upsilon$.
red, yellow	±	Crystals elongated on the orthodiagonal. Pleochroism very strong. 𝔞 orange to lemon-yellow, 𝔟 amethyst to rose-red, 𝔠 deep-red. Optic axial plane ‖ (010).
brown	±	Crystals elongated on the orthodiagonal. Pleochroism, 𝔞 clear yellowish-brown, 𝔟 chestnut-brown, 𝔠 dark greyish-brown. Optic axial plane ‖ (010).

GROUP.

green	±	Pleochroism for vibrations ⊥ (001) yellowish to reddish. ‖ (001) green. Cleavage-laminæ flexible but not elastic. Results from the decomposition of biotite, hornblende, etc.
„	±	Pleochroism for vibrations ⊥ (001) brownish-red, brown, yellow. ‖ (001) emerald-green, blue-green.
„	−	Ditto ditto Twinning, as in the micas, common. Optic axial plane ‖ (010). Dispersion inclined $\rho < \upsilon$.
colourless, greenish, yellowish	+	Occurs in spherulitic groups and rosettes, in the vesicles of basic lavas.
colourless	+	The crystallisation is generally regarded as rhombic.
„	+	Dispersion weak. Optic axial plane inclined about 20° behind a normal to (001). Obtuse bisectrix ⊥ *b*. Kaolin is an alteration product of felspars.

ALTERATION-PRODUCTS OF FEL-

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E.
SAUSSURITE . .	Granr. and Fibrous						
KELYPHITE . .	Fibrous						
LEUCOXENE . .	Granr. to Fibrous						

ZEOLITE

NATROLITE . .	Rhc.	(110)	+	straight	very weak 1	low, not above blue of 2nd ord.	94°–96°
SCOLECITE . .	Mon.	„	−	22° with c	ditto	low, 1st ord.	56°
STILBITE . . . (Desmine)	Mon.	(010)	−	8° with c	ditto	„	53°
PHILLIPSITE .	Mon.	(001) . (010)	+	3°–15° with a	ditto	„	
THOMSONITE . .	Rhc.	(010)	+	straight	ditto	very high, to bluish-grey of 4th ord.	83°
ANALCIME . .	Cubc.	(100)	−	Often shows weak double refraction	ditto	very low, not above iron-grey 1st ord.	

SERPENTINE

SERPENTINE . .			+				
CHRYSOTILE . .	Rhc. ?		+	straight	very weak 1	low, 1st ord.	variable up to 50°

SPAR, GARNET, AND ILMENITE. TABLE VII.

Colour in thin section.	Sign in the direction of elongation.	Notes.
		Essentially a mixture of minerals of secondary origin, chiefly zoisite or epidote with a felspar, not unfrequently albite. It results from the alteration of plagioclastic felspars in gabbros and dolerites. Saussurite is grey, greenish-grey, sometimes with a bluish tinge, occasionally almost white. It is an aggregate of fibres and granules, usually of exceedingly fine texture. Garnet, tremolite, chlorite, etc., may be present.
		Kelyphite forms borders to garnets (pyrope) in peridotites and serpentines. According to Becke, the radially fibrous portion of kelyphite consists of picotite (isotropic) and hornblende (doubly refracting) with a clear outer border, formed of a mixture of hornblende, bronzite, and diallage. He regards it as the result of a reaction between pyrope and olivine, *i.e.*— Pyrope + Olivine = Spinel + Hornblende $Mg_3Al_2Si_3O_{12}+Mg_2SiO_4=MgAl_2O_4+Mg_4Si_4O_{12}$. In the variety of spinel, picotite, Mg is partly replaced by Fe and Al_2 by Cr_2. In reflected light kelyphite appears pale greyish-brown.
		Leucoxene is an alteration product of ilmenite, sometimes granular in structure, at others fibrous, the fibres lying at right angles to the surface of the ilmenite. In reflected light it is white, yellowish, greyish, or brownish. In transmitted light it is nearly opaque, except in very thin sections, when it shows strong double refraction. The brownish colour of some leucoxene is probably due to a sagenitic intergrowth of rutile. The alteration of ilmenite may sometimes result in anatase.

GROUP.

colourless, yellowish	+	Optic axial plane ‖ (010). Dispersion $\rho < \upsilon$.
colourless	−	" " " ⊥ (010). " "
"	−	" " " ‖ (010).
"	+	" " " ⊥ (010). " "
"	±	" " " ‖ (001). " "
"		

GROUP.

colourless, greenish, yellowish		Ordinary serpentine and the fibrous variety, chrysotile, are in most cases the result of the alteration of olivine or hornblende, and often of augite. The serpentines derived from olivine show an irregular mesh-structure; those from augite a rectangular grid-structure (90°) and those from hornblende a lattice-structure (124°).
ditto		

SERPENTINE

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E
Bastite . . .	Rh^c.	(010)	−	straight	weak 2	low, not above yellow, 1st ord.	20°–90°
Antigorite .	Rh^c.	"	−	"	ditto	not above blue of 2nd ord.	"

CARBO-

	Cryst. Syst.	Cleavage.	Opt. Sign.	Extinctions.	Relief.	Interf. Col.	2E
Calcite . . .	$\frac{\text{Hex.}}{2}$	κ $(10\bar{1}1)$	−		weak 2	very high, 4th ord.	
Aragonite . .	Rh^c.	(010)	−	straight	medium 3	ditto	80°
Dolomite . .	$\frac{\text{Hex.}}{2}$	κ $(10\bar{1}1)$	−		ditto	ditto	
Chalybite . .	$\frac{\text{Hex.}}{2}$	"	−		ditto	ditto	

IRON

			Colour in reflected light.	Colour in transmitted light.
Native Iron .	Cub^c.		iron-black	opaque
Magnetite . .	Cub^c.	(111)	bluish-black	Opaque in the thinnest sections, but in extremely thin crystals forming inclusions in mica, it is transparent and of pale-brown colour
Ilmenite . .	$\frac{\text{Hex.}}{2}$	κ $(10\bar{1}1)$	iron-black, with slight tinge of brown	opaque
Hematite . .	$\frac{\text{Hex.}}{2}$		iron-black to greyish-black with tinge of red. Earthy condition red	In thick crystals, or when earthy opaque. In very thin crystals (eisenglimmer) red, orange, yellow. Titaneisenglimmer pinkish madder-brown
Limonite . .	Am.	none	yellowish-brown, dull	opaque
Pyrites . . .	Cub^c.		brass-yellow	"
Graphite . .	$\frac{\text{Hex.}}{2}$	κ (0001)	greyish-black to grey. No metallic lustre	opaque, even in the most minute grains and thinnest sections

Colour in thin section.	Sign in the direction of elongation.	Notes.
greenish		Optic axial plane ‖ (100). Results from the alteration of rhombic pyroxene.
yellowish		Pleochroism feeble. Chiefly results from the alteration of augite.

NATES.

colourless		Lamellar twinning on κ (01$\bar{1}$2) very common. No pleochroism, but strong absorption of light, O > E.	
"	—	Optic axial plane ‖ (100). Dispersion $\rho < \upsilon$. Twinning ‖ (110), but, in rocks, aragonite only occurs in rod-like aggregates or in compact masses.	
colourless, yellowish		No pleochroism, but strong absorption, O > E.	*General Note.* All of these carbonates are soluble in acids with effervescence, the two former in the cold, the two latter in hot acids.
yellowish brown		Often becomes altered to limonite.	

ORES.

Occurs in the basalts of Greenland and in the gabbros of the Western Isles of Scotland. The surface of a section containing native-iron when treated with a solution of copper-sulphate has a film of metallic copper deposited upon the iron.

Crystals frequently give square or triangular sections. Parallel grouping common. Also occurs in irregular grains and patches, sometimes with intermixture of pyrites.

Crystals of tabular habit, giving sections, which when ‖ κ (0001) are hexagonal or trigonal, when $\perp$ κ (0001), lath-shaped. Often altered to leucoxene. Tetartohedral faces met with on the larger crystals.

Specular-iron mostly in six-sided tables with separation-planes ‖ κ (10$\bar{1}$1), due to lamellar twinning. The translucent crystals of micaceous hematite (eisenglimmer) show pleochroism O > E. O brownish-red, E yellowish-red. In earthy condition occurs as a finely disseminated pigment.

Occurs as an alteration product, not only of other iron ores, but also forming pseudomorphs after biotite, hornblende, etc.

Occurs in pentagonal dodecahedra or in cubes, also in irregular grains or patches, often intimately associated with magnetite or ilmenite.

Frequently occurs in rocks as a finely granular pigment. The particles show no definite crystalline form. Often occurs in intimate admixture with magnetite, limonite, and pyrites.

INDEX TO DETERMINATIVE TABLES.

The microscope employed for petrological work should be provided with a rotating stage divided to degrees, Nicol's prisms and arrangements for convergent polarised light. As a rule, greater amplification than that afforded by a quarter-inch objective is not required, but one or two objectives of lower power are essential. A quartz-wedge, a quarter-undulation mica plate, and a bull's-eye condenser are necessary adjuncts.

In the microscope devised by Mr. Allan Dick, manufactured by Messrs. Swift & Son, the stage is fixed, while the polariser and analyser are capable of simultaneous rotation. By this arrangement the necessity for centring gear is abolished. The stage and tube-fittings of this instrument admit of a rapid change from parallel to convergent light.

Should higher powers than a quarter-inch be required, it is desirable to use immersion objectives capable of focussing through moderately thick covering-glasses.

GENERAL INDEX

The Names of Structures are Printed in Italics.